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ABSTRACT

Explored were the effects of starvation during infancy on the learning abilities of 50 children when evaluated between 5 and 14 years of age. All Ss had suffered from pyloric stenosis, a condition which prevents passage of food from the stomach, in infancy for periods ranging from 2 days to 3 weeks. Ss were given five tests of various learning abilities, were evaluated for physical development, and were rated by parents and teachers for social maturity and school behavior. Scores of Ss were compared with those of 44 siblings and 50 control Ss (matched for age, sex, and parental education). Significant correlations ranging from .25 on the Vocabulary Test to .43 on the Auditory Memory Test were found between severity of starvation and scores on all tests of learning abilities with Ss who had had a greater than 20 percent weight deficit in infancy showing significantly poorer scores. Analysis of individual tests suggested that starvation within the first 3 months of life has a long lasting effect on short term memory and attention. Starvation onset between 21 and 30 days of age was significantly related to school problems. Physical development was not found to be affected by early starvation. (Author/DB)

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REPORT

EFFECTS OF INFANT STARVATION ON LEARNING ABILITIES

National Institute of Education Project No. NE-G-00-3-0034

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EFFECTS OF STARVATION IN INFANCY ON SUBSEQUENT LEARNING ABILITIES

ABSTRACT

This study explored the effects of starvation ranging from 2 days to 3 weeks, on specific subsequent learning abilities.

Starvation was defined by the medical condition of Pyloric Stenosis (PS) which prevents passage of food from the stomach to the Duodenum in early infancy and may be corrected surgically. Thus, starvation was brief, defined and unassociated with social deprivation or poverty. Data on severity and time of onset of starvation were gathered from hospital records of the subjects and assessed independently by two medical doctors. Severity of starvation was expressed by the percentage of weight deficit in infancy relative to the norm of expected weight extrapolated from the weight at birth.

Three groups of subjects were studied: 1) 50 index cases between 5 and 14 years old who had been treated for PS in infancy, 2) 44 siblings of the index cases, 5 to 15 years old, and 3) 50 control subjects matched by age, sex and parental education to the 50 index cases. All subjects were white. Those whose mothers had complications during pregnancy, delivery or who suffered later injuries were excluded. No significant differences were found between groups on:

duration of pregnancy, mother's age, birth weight, number of siblings, and number of surgeries in the child's history. Several learning abilities involving auditory and visual channels of communication, automatic and representational levels of cognitive organization, were assessed by: Peabody Picture Vocabulary Test; Vocabulary, Coding, and Auditory Memory (Digit Span) tests from the Wechsler Intelligence Scale for Children; Visual Memory from the Hiskey-Nebraska Test of Learning Aptitude; Raven Progressive Matrices; and the Reading and Arithmetic tests from the Wide Range Achievement Test. The subjects' physical development was assessed by measures of head circumference, height and weight. In addition, the parents of each subject were interviewed and asked to evaluate their child on the Parental Estimate of Development Scale (PEDS) and the Vineland Social Maturity Scale (VSMS). The subjects' teachers were asked to evaluate them on the Ottawa School Behavior Checklist (OSBCL).

For the scores on each of the above mentioned measures intergroup comparisons between the index cases and the two control groups, as well as intragroup comparisons between index cases who had different degrees of starvation at various times of onset, were carried out.

Significant correlations ranging from .25 on the Vocabulary Test to .43 on the Auditory Memory Test, were found between severity of starvation and scores on all tests of learning abilities and PEDS.

Index cases who had a 10% or less weight deficit in infancy did not have significantly different scores from their siblings and matched controls. Greater weight deficits, especially 20% or higher, were associated with significantly poorer scores on tests of learning abilities and social maturity (VSMS). Most consistent findings were observed on the Coding and Auditory Memory tests, supported by the findings on the Visual Memory Test, suggesting that starvation within the first three months of life has a long-lasting effect on short-term memory and attention.

Starvation onset between 21 and 30 days of age was significantly related to school problems associated with Immaturity, Overactivity and Conduct Factors on the OSBCL.

Physical development was not found to be affected by starvation.

In summary, a brief period of severe starvation in early infancy, uncontaminated by socioeconomic conditions was found to have a long-lasting effect on learning abilities and general adjustment in later childhood.

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PREFACE

The study of malnutrition and its effects on cognitive processes has recently expanded greatly, cutting across several disciplines and synthesizing the information collected by them. The motivating force behind this interdisciplinary effort is the need to cope with one of the most crucial problems facing man today--the rapid growth of the world's population and the threat of starvation. More than half of all children in the world are "at risk" from the effects of protein deficiency serious enough to limit brain growth (Keppel, 1967). The apathy typical of chronic protein deficiency which translates into diminished learning potential is estimated to affect 350 million children, or 7 out of every 10 children under the age of 6 in the entire world (Keppel, 1967). It is clear that attempts to achieve better learning should start with understanding and eradicating factors which restrict normal development of the brain. The majority of children afflicted by malnutrition do not die (Cravioto and Robles, 1965) but the long-term effects may be equally tragic in terms of human suffering and wasted potential. Thus, greater understanding of the nature and extent of these effects is extremely important.

The aim of this study is to investigate the possible effects of defined, relatively short periods of starvation in early infancy on later learning abilities.

Chapter I

THEORETICAL BACKGROUND

Introduction

Many personality traits and cognitive abilities of the older child and the adult are ascribed by personality theorists and cognitive psychologists to experiences and events in infancy and early childhood. Recent evidence suggests that not only psychosocial but also physical environments produce profound and lasting disturbances of the anatomical, chemical, and thus developmental and behavioral pattern of the organism. This course of events has been termed "Biological Freudianism" (Dubos et al. 1966). Within the Biological Freudian theoretical framework nutrition plays a major role. The gathering of experimental evidence for a permanent, measurable effect on early nutritional deprivation on brain development and mental abilities has proven to be a task of great complexity. It must be emphasized that evidence of the effect of nutritional deprivation on physical growth of the brain does not necessarily imply an undoubted association between early undernutrition and later impairment of higher mental processes. There is a general ignorance of the connection, if one exists, between intellectual functions and the molecules of which the brain is composed.

The isolated effects of malnutrition are difficult to establish in studies of human subjects. Any attempt to investigate a causal relationship between undernutrition and learning abilities in humans is clouded by the intricate network of sociocultural factors. Research involving animal subjects permits the control of more variables and the developmental study of the brain by a variety of techniques. However, if we are to extend the findings of animal studies to man, we must face the difficult problem of interspecies extrapolation. With this proviso, studies on animals and humans should be examined for their contribution to our understanding of the problem.

Studies on animals allow for greater freedom in manipulation of variables and for the application of various techniques to implement malnutrition and to measure its effects. Animal studies however, also involve some limitations that will be considered in the following section.

a) Research Problems in Studies Involving Animal Subjects

A cause and effect relationship between malnutrition and behavior is difficult to establish, due to the large number of confounding variables involved, whether the subjects are animals or humans. The general procedure in animal studies is to undernourish the animals for the desired length of time, then feed them diets of optimal composition so as to restore them to normal health (nutritional rehabilitation). Testing takes place after the animals have recovered from the nutritional deprivation.

Several methods have been devised to modify experimentally the nutritional state of neonate and infant animals.

In one procedure (Eayrs & Horn, 1955; Howard & Granoff, 1968) the young animals are removed from their mothers for long periods of time daily leading to a period of starvation. This procedure involves not only a general reduction in nursing care, but the accompanying physical and social isolation which could have an effect on the young animal independant of nutrition. A more accepted and widely used method is the method of alteration of litter size during the suckling period (Kennedy, 1957). After birth, rat pups are distributed among the mothers so that they nurse small (3-6), intermediate (8-12), or large (about 16) size litters. The pups of small litters tend to become overweight, those of the large litters underweight, reflecting conditions of over and undernutrition. There are two basic problems involved in this method: (1) Some mothers are capable of assuring good growth of the pups, even when provided with a large litter; and (2) In each large litter a competition ensues among the pups such that the stronger grow at the expense of the others (Altman et al., 1970). A third technique for dietary deprivation in animals involves changes in food intake of the lactating mother (Altman, Das, Sudarshan & Anderson, 1970). The drawback of this method is its effect on the emotional state of the mother. Finally, a fourth method involves individual feeding of each animal to control quantity and composition of nutritional intake (Messer, Thomas, Teressa & Dallman, 1969). This method has obvious advantages over the other two, but does also involve "unnatural feeding of the animals and separation from their mother.

There are two general stages in the development of any tissue. The first stage is a stage of cell division which results in an increase of number of cells. The second stage involves an increase in the size of the cells formed in the previous stage. The effects of undernutrition on brain development may be considered in relation to the above stages in cell development.

Enesco & Leblond (1962) suggested a biochemical method for determining cell size and cell number of various organs including the brain through measuring DNA/RNA, and protein content. Since diploid cells have a constant concentration on nuclear DNA, the total DNA of an organ provides a good estimate of the number of cells composing it. The ratio of protein to DNA or RNA to DNA, gives an estimate of cell size. This method has been adopted in studying the brains of animals sacrificed after different nutritional treatments (Winick and Noble, 1966).

There is a basic limitation in animal studies dealing with the relationship between malnutrition and later learning abilities. As Barnes (1971) points out, in measuring learning performance in animals, it is necessary to reward the animal for a correct response or to punish it for an incorrect one. Rewards are usually in the form of food or water, and punishment in the form of aversive stimuli such as electric shock or exposure to cold water. Since the previously malnourished animal exhibits unusually strong responses to all these situations, it follows that the process of learning will be influenced by such behavioral abnormalities. Therefore, it must be concluded that the interpretation of learning performance as a measure of intelligence or capacity to learn in the malnourished animal must proceed with caution.

Before any further discussion on empirical data collected in this field, attention should be called to some theoretical and research design problems in human studies.

b) *Research Problems in Studies Involving Human Subjects*

The concepts of malnutrition and undernutrition are used interchangeably in most of the reported studies on human subjects. Where a distinction between these concepts is made, malnutrition is referred to as a specific deficiency in either calories, proteins or vitamins, whereas undernutrition is referred to as a general deficiency in the intake of all types of food. Starvation is viewed as a severe form of undernutrition. Most of the studies on malnutrition in human children discussed here were those involving the most severe manifestations of malnutrition referred to as marasmus or kwashiorkor.

Marasmus, in its most clear-cut form, is due to partial starvation or, in other words, a deficiency of calories as well as proteins. Marasmus frequently results from early weaning of the infant and the substitution of an improperly constituted formula so that the infant does not receive its full quota of nutrients, particularly calories (Barnes, 1971).

Kwashiorkor is caused by an extremely low intake of protein but with a more or less adequate supply of calories. Frequently kwashiorkor begins to develop when the mother gives birth to another child and the older sibling is weaned. If this happens when the child is 1 to 3 years of age, and in the process of weaning, is fed with low protein, starchy types of food, kwashiorkor is especially likely to occur (Barnes, 1971).

Malnutrition studied in human subjects is most often an out-growth of social conditions such as poverty, ignorance, overcrowding, poor hygiene, diseases and other conditions that prevent the child from receiving the amount and kind of nutrition essential for body growth, including brain development. The fact that body and brain growth is arrested in cases of malnutrition, has been empirically demonstrated. The crucial problem now is to determine the causal links between physical and intellectual retardation observed in malnourished subjects (Hallahan & Cruickshank, 1973).

Many studies indicate that poor psychological development is associated with, though not necessarily caused by, malnutrition. Two phenomena may be associated with a third independent variable which may be a factor in the causation of both. Poor nutrition in children is often associated with illiteracy or even retardation in the parents and with poor child-rearing practices. Where there is deficiency of nutrients. There is often also a deficiency of intellectual stimulation. Therefore, factors which are important in the etiology of malnutrition may also be factors in the etiology of impaired psychological development (Latham et al., 1971).

Cravioto, DeLicardie and Birch (1966) have suggested the following two theoretical schemes to depict the interrelationship among nutritional deprivation, physical or mental retardation, and sociocultural conditions.

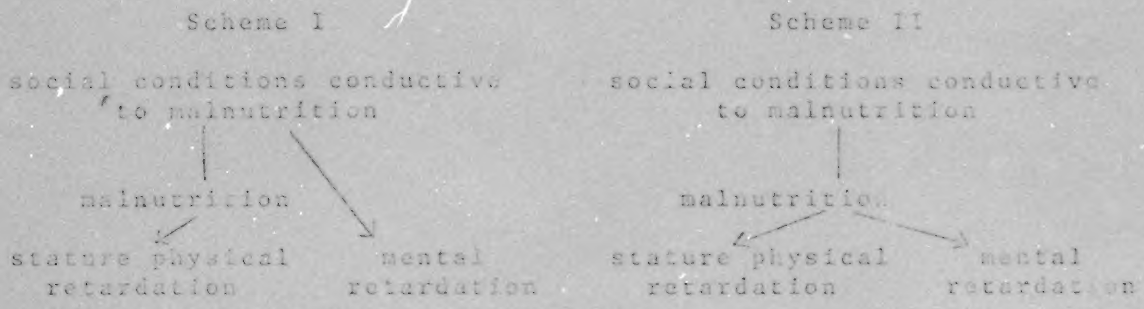
Scheme I
social conditions conductive to malnutrition
malnutrition
stature physical retardation
mental retardation
Scheme II
social conditions conductive to malnutrition
malnutrition
stature physical retardation
mental retardation

Figure 1. Social conditions and retardation (Cravioto, et al., 1973).

Research data have not produced conclusive evidence favoring one scheme over the other. Cravioto's writings tend to support the second scheme. Scrimshaw and Gordon (1968) combine the two theoretical schemes suggested by Cravioto et al. Their scheme has been recently evaluated by Hallahan & Cruickshank (1973) as the most rational, theoretical explanation for the relationships in question. Scrimshaw and Gordon believe that both social and nutritional factors can affect mental development independently, but also interact strongly (Figure 2). The end result is a combination of the effects of each of the two factors working alone plus further contribution from the interaction of the two.

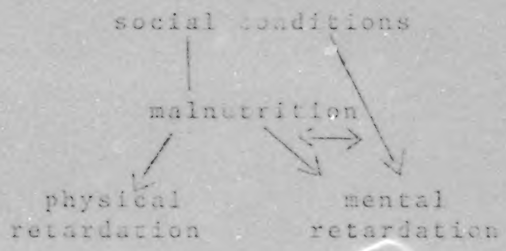

Figure 2. Theoretical interpretation of the relationship between malnutrition and retardation (Schrimshow & Gordon, 1968).

The available research findings are not adequate for the clarification of the above theoretical and practical problems. Many human studies in this field have serious limitations which cloud the validity of the findings. These are of five major types: 1) Numerically deficient and inadequately controlled sampling techniques. 2) Incomparability of the findings across cultures, different types of measures, standardized and unstandardized tests, many of the field studies were carried out in different areas of the world, utilizing a variety of measures of mental abilities, some of which were non-standardized. This type of limitation does not allow for a conclusive summary of research findings or for a direct application of these findings to subjects in western civilizations. 3) Lack of a uniform empirical definition of what constitutes a state of nutritional deprivation as well as inaccurate determinations of nutritional diseases. Dayton (1969) points out an additional difficulty, namely that clinical signs of malnutrition are not present in milder cases of malnutrition. This further complicates the problem of precise diagnosis. There are diffuse deficits of growth attainment, some of which easily escape notice, since they may never depress attainment below the lower limits of normality. Yet, these deficits in growth could have a long-range effect out of all proportion to their magnitude (Dobbing, 1970). 4) Inadequacy of measures. Measures of head circumference and body height and weight are the most frequently used physical measures of the effect of nutritional deficit on physical development. The head circumference measurement yields a rough approximation of brain size. Head size is affected not only by nutritional factors but also by factors such as size of scalp, temporal muscle, and bony skull, and there is also a relationship to body weight and height (Garn, 1966, Frisch, 1970). Though a significant correlation exists between head circumference and brain size, there is no knowledge of the direct relationship between brain size and intelligence (Scrimshaw, 1967). The measurement of height and weight are affected by a multitude of factors of which nutrition is but one. 5) Inadequate control of the multitude of sociocultural and biological elements associated with malnutrition. Infection, psychological and social deprivation, parental education, lack of motivation, and other factors related to poverty may be capable of impeding learning, as well as precipitating specific learning disabilities and mental retardation (Dayton, 1969).

It is obvious that, if the role of nutrition in mental development is ever to be determined, these factors must be untangled and held constant by tightly controlled research designs (Hallahan & Cruickshank, 1973). A well controlled experimental research study on the effects of malnutrition, is for obvious reasons impossible to carry out with human subjects.

Malnutrition and Physical Growth of the Body

The growing brain is part of the growing body. Before dealing with the effects of nutritional deficiencies on the development of the brain, a review of research on nutrition and body growth is necessary.

A long and severe famine during the siege of Leningrad in World War II led to a reduction in average birth weight of 400-500 grms. (Antonov, 1947). A less severe and briefer famine during the same period in wartime Holland led to a reduction by 240 grms. in average birth weight (Smith, 1957). A similar decline was recorded in 1944 in Japan (Kono et al. 1962). This study and the one by Gruenwald (1967) show that as economic conditions improved in Japan after the war, the birth weight of children increased "conspicuously".

Whereas severe dietary deprivation reduces birth weight and may affect the subsequent growth potential of the child, milder forms of malnutrition, i.e. the kinds that are prevalent in economically disadvantaged groups, do not have such obvious effects on birth weight but may affect the subsequent growth potential of the child. Behar (1968) found that in

Thailand, Southern India, Malaya, New Guinea, Uganda, Mexico and Guatemala, the size of children at birth was similar to that of European and North American children. At about 6 months of age, around the time they were weaned, the growth rate of these children began to fall rapidly. This reduction in weight was caused by substituting breast feeding by bottle feeding that is high in starchy substances and low in protein. Children of high socioeconomic groups of different racial and national background (U.S. white; U.S. Negro, Japanese; Indian; Guatemalan) have similar growth rates between 1-12 months, and differ as a group from children of low socioeconomic groups of diverse origins. Such differences persist in school-age children. No weight differences were found between school-age children from high socioeconomic groups across different countries (U.S. white; private schools in Guatemala and Panama). However, children from high socioeconomic groups differed from those in low socioeconomic groups (public schools in Guatamala, India, Malaya and Thailand), in their own countries (Guzman, 1968). In Costa Rica where the low income children are predominantly of European origin, the growth retardation is comparable to that of the low income children of Guatemala who are of Malayan origin (Scrimshaw & Gordon, 1968).

In summary, the studies suggest that interracial differences are small compared to differences between socioeconomic groups. These differences are also undergoing change, possibly due to a growing similarity in nutrition between the different groups. Bakwin and Mclaughlin (1964) found that in the 1930's, entering college students from private schools (higher socioeconomic group) were taller and heavier than students from public schools. In the succeeding 15 years the height and weight of students from public schools increased and approached that of students from private schools, whereas the latter group showed no further change in stature.

Follow-up studies of children who have been treated for infantile nutritional deficiencies indicate that, during the recovery period, their physical growth is very rapid at first (Cravioto et al., 1966), but continued observations over sufficiently long periods of time show that the child never completely catches up with those whose diet has been adequate from the start. Growth stops at the usual chronological age, and the height as well as head circumference of these subjects as adults is significantly lower than that of their healthy peers (Cravioto et al., 1966).

Stoch and Smythe (1967) conducted a longitudinal study in South Africa with two groups of children. The first group of 20 children suffered from severe malnutrition; the second group were well nourished infants. The marked differences in physical and mental development of these two groups have persisted throughout the 11 years of the study. The malnourished group has also remained smaller than the control group.

In Colorado, Chase and Martin (1970) studied 19 children admitted to the hospital between 1962 and 1967 at less than a year of age with generalized undernutrition, and compared them to controls chosen on the basis of age, sex, birth weight and race. All subjects were born and followed in the same hospital. Three and a half years later the children were re-examined. At this time, 68% of the test children as compared to 14% of the controls were below the third percentile in height, 53% of the test children as compared to 21% of the controls were below the third percentile in weight, and 37% of the test children as compared to 10% of the controls were below the third percentile in head circumference. Physical growth was found to correlate negatively with the duration of undernutrition in the first year of life. The 10 children who were admitted to the hospital because of malnutrition lasting during more than the first four months of age, were lower than the other children on all three of the above indices. Three and a half years later, nine of the ten were below the third percentile in height, eight of ten were below the third percentile in weight, and six of the ten were below the third percentile in head circumference.

The relationship between malnutrition and body growth has been empirically established. More attention is directed currently toward the questions of the existence of critical periods in development and the related question of reversibility or irreversibility of the effect of malnutrition during different periods of development. One possible answer suggested by Winick and Noble (1966) is based on their studies from which they concluded that undernutrition can have a different effect on organ cell size or cell number depending on the phase of development of the affected organs. Early deprivation led to reduced cell number in all organs and to permanent retardation, presumably because once developmental cell proliferation stops, the normal cell number cannot be achieved. Later deprivation had an irreversible effect only on those organs in which cell acquisition was still in progress.

Winick and Noble (1966) found that raising pups in large litters from birth to weaning, resulted in a decrease in weight, protein, RNA and DNA content in all organs, indicating a reduction in cell number but not in cell size. After weaning when these animals were allowed to eat as much as they wanted, normal growth did not ensue. Rats raised on a restricted diet from weaning to 42 days of age, showed a proportional reduction in weight, protein, RNA and DNA in most organs except in lungs and brain. In the lungs and brain, protein and RNA ratios were reduced but total DNA was not reduced. This indicates that the size of the cells was affected but not their number. After these animals were put on a "free diet", the brain and lungs regained normal size.

In another study, Winick and Noble (1967) found that the organs of infant rats raised in small groups (3-6 per mother) had more cells than organs of rats raised up to 9 days in groups of 18 to a mother. A very interesting finding was that rehabilitation of this later group, by keeping them in groups of only 3 to a mother, from 10 days on until weaning, led to normal recovery in cell number.

Guthrie and Brown's (1968) findings also indicate that the brain was irreversibly damaged only by undernutrition occurring prior to weaning. They suggest the "sparing" of the brain after weaning but a decrease in brain size and DNA concentration following malnutrition during the preweaning period.

In summary, the effect of malnutrition on a developing organ is irreversible when it occurs during the period of cell division, and reversible when it occurs during the period of cell growth. A reduction in cell number leads to permanent damage whereas a reduction in cell size can be corrected by adequate nutrition at a later period.

Malnutrition and the Developing Brain

Early studies on the effect of malnutrition on brain development pointed to the so-called "sparing effect". It was believed that of all organs of the body, the brain during its growth period is least affected by starvation (Hatai, 1904). This widely accepted but partially incorrect conclusion was based on observations of rats weaned at 21 postnatal days and then undernourished. In 1917 and 1918, Sugita suggested that the effect of undernutrition on the development of cerebral cortex is better studied in suckling rats during the first three postnatal weeks than after this period. He emphasized that the normal growth of the cerebral cortex in the rat reaches adult weight during the first three weeks of life, whereas the maximal increment of body growth occurs between three and seven weeks.

Recent investigations (Dobbing, 1965) have established that in rats, undernutrition during the first three weeks of life causes a permanent cerebral lesion. In contrast, undernutrition after three weeks of age has a progressively smaller effect and the brain recovers histologically and biochemically when body weight is restored (Dobbing et al., 1965 ; Dickersen & Walmsley, 1967; Winick & Noble, 1966).

The human newborn is a "perinatal brain developer" i.e. the brain is undergoing its growth spurt at the time of birth. The average weight of the brain in a full term human infant is 335 grms., compared to 516 grms. in a three-month old infant (Dekaban, 1970). The production of human brain DNA is two-thirds complete by birth and ceases 5 months after birth (Winick, 1968).

The two main processes morphologically associated with the growth of the human brain at the time of birth are increase of cell cytoplasm with extension of axons and dendrites and myelination. The former is largely a process of protein synthesis, suggesting special vulnerability to nutritional deprivation at this time.

Two main overlapping hypotheses about the vulnerability of the developing brain have already been extensively tested (Dobbing, 1970). The first hypothesis states that undernutrition during the growth period, i.e. during the period in which cell division occurs in any tissue, will cause permanent reduction in the number of cells of this tissue.

Undernutrition that occurs at a later stage of development will affect only what develops in the cell at that time, namely the cell size. Reduction in cell size is reversible, and will recover with restoration of normal nutrition. There is no doubt that this simple hypothesis clearly explains many of the phonomena connected with the "catch-up potential" of different parts of the body (Dobbing, 1970). The other main hypothesis (Dobbing, 1968) states that the brain is likely to be most vulnerable to permanent restriction from undernutrition during the period of the "brain growth-spurt", the transient period during which it is passing through the rapid phase of its sigmoid growth trajectory. Dobbing (1970) lists the following corollaries: 1.) The nearer the period of undernutrition is to the growth-spurt, the milder it need be to produce permanent restriction; and the further away, the more severe, until in adulthood there is no great effect on brain composition from very severe starvation. 2.) In view of the different rates of growth in different brain regions and along different parameters of measurement, undernutrition at any one stage will produce different effects in relation to the regional velocity of growth obtaining at the time (Dobbing, 1970).

Though these two hypotheses have much in common, they differ in that the period of cell division occupies only the first part of the brain growth spurt, the second part involves events such as the growth in number and length of dendritic processes, the development of synaptic connections between them, and myelination. None of these processes is directly concerned with cell division, yet all may be vulnerable during the period of rapid development.

One of the basic problems in human studies is to identify the period of the brain growth-spurt. The use of chemical indices for studying components of brain structure is now widespread and offers a comparatively simple, if sometimes crude, method of assessment (Dobbing, 1970). Thus, total tissue DNA is an index of total number of cells, and its concentration per gram of fresh weight is an index of cellularity. Myelin lipids represent myelination and protein: DNA ratios have been used as an index of cell size. There are numerous problems which make the study of the human brain extremely difficult. There has to be a sufficient number of brains in order to allow generalization of findings. The problem of obtaining normal brains from dead children is further complicated by the possible deterioration of brain tissues in the time interval between death and examination (Dobbing, 1970). A study involving the largest number of human brains was reported by Dobbing (1970). More than 200 human brains ranging from ten weeks of gestation to six years were selected from fetuses and children within one standard deviation of the expected body weight for their age, and without gross pathology of the central nervous system. The DNA and cholesterol level of each brain were studied, since neither of these significantly deteriorates under ordinary conditions during the time elapsing after death (Dobbing, 1970). Dobbing derived the following conclusions from his study:

(1) DNA estimations reveal a separate growth-spurt from 15-20 weeks of human gestation which is distinct from the main period of cell division. This latter extends from about 30 weeks of gestation to at least the end of the first postnatal year. The early period is almost certainly neutral; the later, glial.

(2) Regional differences in growth rate, and the general sequence of events in human brain growth are identical with those in all animal species studied, except for the timing of events in relation to birth.

(3) The major growth-spurt period in humans is predominantly postnatal, especially in the great bulk of myelin which is laid down after the arrival of glial cells which produce it.

Winick, Rosso and Waterlow (1970) studied the biochemical growth of the brain in (a) "normal" children who died between birth and 2 years of age as a result of accident, poisoning, or other causes not involving the nervous system, and (b) children of the same age who died following severe marasmus. In the cerebellum of the normal children there was a 12-fold increase in protein, a 10-fold increase in RNA during this period, and during the first 10 months, a 4-fold increase in DNA. The effect on cell number was much greater in the cerebrum and cerebellum than in the brain stem.

In summary, studies on animals and human subjects have generally proven the existance of critical periods in brain development, during which malnutrition can lead to irreversible damage. In relation to these critical periods, Dobbing (1970) points to a very interesting phenomenon; growth retardation does not alter the timing of the growth-spurt in the brain. Thus, there is no delay in brain development. There is simply a reduction in the process of development, which nevertheless occurs at its prescheduled time. None of the individual velocity peaks of total brain weight, DNA, or cholesterol accumulation are shifted in time. They are merely reduced in height; and since there is no resurgence or "catch-up" in the restoration of the missing food, the effect is a permanent reduction. In other words, the brain is an organ which has a once-and-for-all opportunity to accomplish certain important processes or development. If this opportunity is lost, it can never be fully recovered.

The effects of malnutrition on the brain are reviewed in the following pages through the discussion of its effects on: 1) different regions in the brain, 2) chemical differentiation of the brain, 3) brain activity, and 4) brain weight.

1) Regional Effects of Malnutrition.

The cerebellum in human subjects passes through its growth-spurt at the same time as the other parts of the brain, but its relative rate of growth is much faster (Dickerson & Dobbing, 1967). This leads to a selective restriction of growth of the cerebellum (Chase et al., 1969).

Similar regional effects of malnutrition on the brain were found in studies on animal subjects. Culley and Lineberger (1968) found that, of the three brain regions examined (cerebellum, pons-medulla and mid and fore-brain), restricted feeding affected most severely the weight and DNA content of the cerebellum. Similar results were reported by Howard and Granoff (1968) and by Cheek et al., (1969). Chase et al. (1969) compared the effects of nursing rats in experimental groups of 16 and 4 per mother on the development of cerebrum and cerebellum at 18 days of age. They found that the weights of both the cerebrum and cerebellum were significantly lower in the undernourished groups, with a reduction of 9.9% in the cerebrum and 18% in the cerebellum. The difference in the cerebrum was attributed to reduction in cell size (with no reduction in DNA). while the difference obtained in the cerebellum was attributed to a reduction in cell number.

In 5 out of 47 patients studied, Nelson and Dean found focal disturbances in the temporal areas of the brain. These have been interpreted as indicative of a local reaction to the generalized state of intracellular overhydration that is a very common feature of severe chronic infantile malnutrition (Frenk et al., 1967). Their usual origin in the temporal lobe may be only a reflection of the lobe's tendency to react more easily to malnutrition than other brain regions.

2) Chemical Differentiation of the Brain

Several studies concerned with the effects of infantile malnutrition on the chemical differentiation of the brain, suggest that nutritional deprivation of suckling rats leads to reduced brain cholesterol and phospholipids (Dobbing and Widdowson, 1965 ; Culley and Mertz, 1965). These findings, as well as those reported by Benton et al., (1966) and Guthrie and Brown (1968), suggest that malnutrition interferes with myelination. Thus, if myelination of neural fibers is deficient, the information traveling along these fibers may be negatively affected.

3) Brain Activity

One of the techniques used in the study of malnourished subjects is the electroencephalogram (EEG). The electrophysiological activity of the nervous system serves to integrate its metabolic and neurochemical processes into functional and performance capabilities. In man and in lower animals, the normal EEG patterns and their developmental sequence have been shown to become abnormal in chronic and acute states of malnutrition, suggesting alternations in normal cellular electrical activity. The abnormal electroencephalographic tracings seen in malnourished subjects generally improve toward normal with adequate nutritional therapy (Coursin et al., 1973). Electroencephalography has been used as a method for studying neural functions in malnourished infants by Sarrouy, Saint-Jean, and Clausse (1963); Engel (1956), Valenzuela, Hernandez, Peniche and Macias (1959); and Nelson and Dean (1959). The EEG recordings have consistently shown changes in the form, frequency, and amplitude of the waves, even in mild to moderate cases. With successful treatment, the EEG tends more and more to conform to that of healthy children of similar age. Finally, when the child is recovering, the abnormalities disappear. The total rehabilitation usually takes from 40 to 60 days (Cravioto, J., 1966).

4) Brain Weight

In most of the studies discussed, the period during which the animal or person was starved was either undefined or prolonged. The question arises as to the effect of a brief period of postnatal fasting on brain development. In an attempt to answer this question, Schain et al. (1973) studied the effect of brief postnatal fast upon subsequent brain development in the rabbit. The rabbit brain like that of the human, develops perinatally. Newborn animals were subjected to a two-way postnatal fast immediately after birth. These animals and matched controls were killed at 60 days of age, and their brains studied. It was found that these fasted animals whose body weight was more than 25% below the control animals at 12 days of age, exhibited a significant reduction in brain weight and constituents at 60 days of age. Cholesterol accumulation was slowed to a greater extent than other constituents, but DNA, RNA and protein levels were also significantly decreased. Those fasted animals whose body weight nearly caught up to the controls after the fast, did not manifest differences of brain size and composition at 60 days of age. This study indicates that the degree of body weight catch-up after a brief postnatal fast will affect subsequent study should be regarded with caution.

Before considering the effects of malnutrition on intellectual abilities, attention will be given to studies demonstrating the relationship between physical and mental development:

In six different communities in Mexico and Guatamala, two of typical Mestizos, one of Zapotec Indians, one of Nahoa Indians, and two of Cakchiguel Indians, high correlations between deficits in height and weight on the one hand, and adoptive developmental scores on the other were found (Cravioto, 1964). No association of statistical significance could be demonstrated between mental scores and cash income, crops income, parents' education, parental hygiene, or type of housing.

Cravioto and Robles (1965) compared a group of previously malnourished children in Mexico with control children of similar ethnic background and age. The children's performance on four cognitive tasks was compared. The malnourished group was found to have a lower performance on all tasks. Cravioto et al., (1966) found that the intersensory skill (functions requiring integration of information coming through several senses) of the tallest 25% of the children was significantly better than that of the shortest children. They assumed that poor nutrition led to the shortness of stature and thus malnutrition was found to be associated with poor cognitive functioning, especially in those functions requiring intersensory integration.

Russian investigators in the Pavlovian tradition infer cortical dynamics from conditioned reflexes. Alekseeva and Kaplanskaya-Raiskaya (Cravioto, 1964) reported that young children fed on a protein deficient diet show lesser ability to elaborate new conditioned reflexes, i.e. the previously well-established reflex responses may be depressed or abolished. The recovery of the conditioned reflexes is slow and reflects the slow normalization of the metabolic processes basic to the functioning of the cerebral cortex.

The Griffiths Scale, which measures different areas of behavior such as locomotor, personal-social, hearing and speech, eye and hand coordination, and performance, was administered in Bogota to three groups of children (Latham and Cobos, 1971): Group I from the low socioeconomic class and recuperating from malnutrition; Group II from the same socioeconomic class, but not malnourished; and Group III from the middle socioeconomic class and also not malnourished. The malnourished children scores most poorly, the well-nourished children from the low socioeconomic class were intermediate, and the well nourished children from the middle socioeconomic class had highest scores on all the factors studied.

In Colorado, Chase and Martin (1970) reported that 19 children admitted to the hospital between 1962 and 1967 at less than a year of age with generalized undernutrition scored poorly on intelligence tests when tested 8 to 11 years later. The mean developmental quotient of the 19 previously malnourished children was 82.1, whereas 16 children chosen as control on the basis of age, sex, birth weight, race and being born and followed in the same hospital, had a mean developmental quotient of 99.4.

Birch et al. (1971) in a recent study compared 37 children who had been hospitalized for kwashiorkor between 6 and 30 months of age, with their siblings closest to them in age who had never suffered from malnutrition. The mean full scale WISC IQ of the index cases was found to be 68.5 compared to 81.5 for the controls. All mean IQ differences were significant at less than .05 level of significance. Three and one half years after the children were admitted to the hospital, the mean developmental quotient for the control children was 99.4 as compared to a mean of 82 for the previously undernourished children ($p < .001$). Test children were particularly low in language. Children admitted to the hospital with undernutrition lasting longer than the first four months of life were most severely impaired. Using the IQ score of 70 as a cutting point, twice as many of the previously malnourished children as their sibs functioned below this level. The largest differences in performance of the two groups were found on the following subtests of the WISC: Information, Arithmetic, Vocabulary, Picture Arrangement, Object Assembly and Coding.

In Columbia, South America, it has been found that children who had suffered from malnutrition had poorer psychological development than controls from the same community who were not subjected to periods of malnutrition (Latham et al., 1969).

Barrera Moncada (1963) has used the Gesell Scale to explore the behavior of previously malnourished children. Performance in all the fields of behavior tested had lower developmental scores than the children of similar age and ethnic group. The better scores were in general motor development and the greatest retardation was in language.

Studies conducted in Peru (Pollitt & Granoff, 1967), Chile (Monckeberg, 1968) and the United States (Chase & Martin, 1970) support the hypothesis of the effect of undernutrition on the motor, adaptive, language and personal-social factors of mental development.

In summary, studies conducted around the world, representing a diverse sample of the world's human population, point to an existing positive relationship between malnutrition and deficits in mental abilities, with the greatest deficits in language and in tasks requiring inter-sensory coordination.

It was demonstrated in previous pages that the brain is differentially affected by malnutrition occurring at different periods in its development. This question of "critical periods" in development was also studied by means of psychological evaluations of intellectual abilities.

Cravioto and Robles (1965) sought to assess the effect of malnutrition that has occurred at three different age periods: below six months, between six and thirty months, and after thirty months. From among the children admitted to the Nutrition Ward of the Children's Hospital in Mexico, all who were suffering from severe protein malnutrition participated in this study. Immediately after any infectious and/or electrolyte disturbances had been corrected, the children were tested by the Gesell Method: (motor, adaptive, language and personal-social tests). The tests were repeated every two weeks during the entire time the children spent in the hospital. Data were collected over one year for 6 infants below 6 months of age, 9 children between 15 and 29 months, and 5 children between 37 and 42 months. The results were in line with previous findings. The subjects who were subjected to malnutrition, scored lower than the norm on all subtests of the Gesell. As the patients recovered from malnutrition, their developmental quotients increased and approached those of the normal population. In the group of subjects who were admitted to the hospital before, the deficit in performance as compared to normal children did not diminish In all children, not all the fields of behavior explored with the Gesell technique recovered at the same speed. Language, which was in general the most affected, returned toward normal at the slowest rate.

Findings reported in animal studies on the relationship between malnutrition and retarded mental abilities, support the basic hypothesis of the positive relationship between nutritional deficiencies and mental dificiencies. In animal studies, the above relationship is approximating a cause and effect relationship by analyzing the brain of the animals after the nutritional treatment and psychological measurement of behavior. Findings that the brain was affected following starvation and so were some mental abilities, suggest the following chain of causality: malnutrition → brain damage → mental deficits. Many of the studies dealing with nutrition and brain development have already been reviewed here. The following studies add the missing link in the above chain of causality i.e. examining the mental abilities of the malnourished animals in relation to the damaged brain.

Barnes et al. (1971), experimenting with baby pigs, found that protein deficiency caused by feeding low protein diets led to the following anatomical alterations in the brain: reduction in number of neurons in all gray matter, especially in the thalamic and medullar nuclei and in Purkinjie cells of the cerebellum; swelling of the neurons with poorly worked axons and dendrites. Similar findings were reported by Platt et al. (1964) in dogs and by Flexner (1966) in mice. Flexer found loss of memory in mice to be related to the degree and duration of inhibition of protein synthesis by puromycin.

After seven years of studying baby rats and baby pigs, Barnes (1971) established the following general principles concerning the causal relationships between early malnutrition and behavioral development. Severe malnutrition, whether in terms of protein deficiency or calorie deficiency, if imposed for a long enough time during a critical period of early development, does cause changes in behavioral development of the animal. The previously malnourished animal exhibits exaggerated excitability or emotionality when it is confronted by a painful or otherwise aversive stimulus. For example, when a rat is placed in a new environment and hears a loud, strange noise, its normal tendency is to stop all motion or freeze in one spot and only after a lapse of time will it begin to move about and explore its surroundings. It has been found that the rat that was malnourished early in life remains immobile for a longer time and returns to normal exploratory activity much more slowly than the control rats. There are many other studies illustrating the phenomenon of hyperexcitability or exaggerated response to an aversive situation (Levitsky and Barnes, 1970). Barnes et al. (1966) report on a number of studies, including their own, which show poor learning performance in animals that have been malnourished early in life. They state that there is a natural tendency for the researchers involved to interpret such results as showing a decreased intelligence or capacity to learn in animals that have been malnourished.

Latham and Cobos (1971) suggest the following new hypothesis concerning the role of malnutrition in retarded intellectual development: The poor performance of many previously malnourished children is not due to pathological changes in the central nervous system, but to a calorie deficiency which has restricted the activities and learning opportunities of the child. It is well known that a chronic calorie deficit will lead to a reduction of activity in laboratory animals or in adult man. This physiological response to a calorie-deficient diet is a protective mechanism to conserve energy. When faced with a chronic deficit in calories, the young child may be expected to conserve his energy for purposes of growth and for essential activities. By restricting his movements and by spending long periods of time passively, the malnourished child may be greatly limiting the time spent playing with his peers, verbalizing with his mother, manipulating objects, stimulating his senses, and so on. His poor performance on subsequent intelligence tests assessing verbal, personal-social, sensori-motor and other skills may be due to the passivity which has characterized most of his waking life, and not to a lack of nutrients affecting his brain growth.

In line with the above hypothesis, Latham et al. (1965) studied the body's activity rate of young children in Bogota, Columbia, utilizing a new method of counting heart rate. During a period of approximately two months, 18 children, 10 of whom had protein-calorie malnutrition and 8 of whom were well nourished, were studied. The malnourished children showed evidence of retarded physical growth (all but one were below 75% of expected weight for age). The mean number of heartbeats per minute of the malnourished subjects was significantly lower than that of the well-nourished controls (Heywood & Latham, 1971), indicating that malnutrition has a lasting effect on body activity. Under this hypothesis intellectual deficits due to malnutrition are caused by the reduced body activity rather than by direct damage to the brain.

The Effect of Starvation as an Early Experience

Viewing the relationship between nutrition and learning through the theoretical framework of "biological Freudianism" should not blind us to the multitude of other environmental and psychological factors which could significantly influence the child's mental abilities either directly or through their influence on the ultimate structure and function of the brain.

Sufficient empirical evidence exists to prove that deprivation of various factors such as maternal care, love and physical handling of the infant, as well as other environmental stimuli can result in a retardation of mental development. A dramatic demonstration of this comes from a study conducted by Harold Skeels at the University of Iowa (1930). Skeels transferred thirteen children from an orphanage to an institution for the mentally retarded. The children were all under three years of age. Before leaving the orphanage their I Q ranged from 35 to 89 with a median of 65. These children were cared for by the older, brighter girls and by women who became very fond of them. The children were given much attention and opportunity for play. A control group of children remained at the orphanage. These children had I Q 's ranging from 81 to 103. There were no significant differences in the children's socioeconomic background or birth history.

When these children were retested, the experimental group was found to have gained 7 to 58 I Q points, whereas the control group with one exception showed losses of 9 to 45 points. Twenty-one years later, Skeels found that all of the experimental group members were self supporting. In the control group, eight were in institutions for mentally retarded or in a mental hospital and one had died. They had completed a median of less than 3 years of schooling compared to 12 years in the experimental group.

Cognitive development through experience may have an effect on the physical development of the brain as well as forming the basis for later behavior.

In enriched environments (i.e. including a variety of visual and tactual stimuli), experimental animals have been found to have significant increases in brain weight and nucleic acid content, dendritic arborization, myelination, acetylcholinesterase content, etc. In contrast, isolation has been shown to have a significant opposite effect on these indices of development (Coursin et al. 1973). Physical development of the brain is directly influenced by its information processing activities particularly in neo-natal organisms (Hunt, 1969).

The assumption that experience leads to actual biochemical changes in the brain was demonstrated by the fact that rats injected with brain construct from rats trained in a certain maze, learned this maze in fewer trials as compared to control rats (Krech, 1969).

The role of experience is central in Piaget's theory of intellectual development. Piaget is fairly brief in his discussion of cognitive development during the first month of infancy. Nonetheless, he does consider this period to be an extremely important one, since it is the crucible from which sensory-motor intelligence will subsequently emerge. This is true in two distinct senses. First, the simple reflexes of the neonate undergo definite modifications as a consequence of environmental contact; in so doing, they imperceptibly become acquired adaptations instead of mere reflexes. Second, the reflex behavior of the first month or so already possesses the faint beginnings of the invariants of functioning--the organization, assimilation, and accommodation which will persist as functional invariants constants throughout development. Between one and four months is the period in which the first simple habits, the basics of sensory-motor acquisitions really come into existence. The need for "cognitive nutriment" of the senses . may be overpowered by the constant hunger drive in infants suffering from starvation, thus interfering with laying the very early layers of cognitive development.

In earlier investigations of protein-calorie malnutrition in infants, apathy was found to be universally present (Cravioto, 1966). The patients lacked the curiosity and activity found in normal children of similar ages and responded sluggishly, if at all, to a variety of stimuli. One of the early signs of recovery was the return of the responsiveness to the environment.

Similar findings were reported in animal studies. Zimmermann et al. (1970) found that monkeys fed a protein-deficient diet exhibited normal learning performance when the test situation was a familiar one, i.e. repeated many times. However, when a new object was introduced into the test situation, the malnourished animals avoid this object and consequently have poor learning scores, in contrast to the control animals which exhibit special attention and curiosity toward a new object. Zimmermann has described this as "neophobic reaction" in protein malnourished infant monkeys. The same phonomenon of avoiding new stimuli was found by Barnes in malnourished baby pigs (1971). These studies suggest that the malnourished animal or child does not react to early "novel" experiences which are essential to normal intellectual development.

In summary, empirical data presented thus far indicate that severe malnutrition affects both physical and intellectual development. The latter can be affected in two ways: 1) Direct effect of malnutrition on the brain. That part of the brain which is undergoing rapid development at the time of severe nutritional deprivation is affected most. Animal and human studies suggest that there are critical periods in brain growth, and that interference with brain growth during those periods causes an irreversible reduction in cell number and a long range deficit in intellectual functioning. 2) Indirect effect of malnutrition on intellectual functioning. The indirect effect is achieved through modification of behavior leading to reduced levels of activity and apathy. Research findings suggest that both possibilities 1 and 2 coexist and jointly produce the effect of malnutrition on intellectual functioning.

The implications of the theory and research presented in this chapter for the questions posed by the present study will be discussed in the following chapter.

Chapter 2

THE STUDY

Pylori Stenosis

The Condition of Pyloric Stenosis

The starvation experienced by the subjects in the present study was caused by pyloric stenosis (PS), a condition in which the pyloric muscle is greatly enlarged and thickened, preventing the emptying of the contents of the stomach into the duodenum. The resulting starvation ranges from a few days to two or three weeks. The average onset of PS occurs at about three weeks of age, the range being between birth and six months. PS is the most common lesion requiring abdominal surgery during the first six months of life. It was first described by Hirschsprung three quarters of a century ago, and has been treated by direct surgical intervention by means of the Fredet-Ramstedt pyloromyotomy for just half a century (Benson and Lloyd, 1964).

PS was once attended by an almost negligible survival rate. However, mortality has become almost negligible due to progressively earlier recognition and prompt surgical treatment. Fewer infants are being admitted now to hospitals in a state of severe alkalosis and malnutrition. The latter fact suggests that this present study might well be a last opportunity to find a population of children who have suffered from different periods of starvation as a result of this particular affliction.

The exact etiology of congenital pyloric stenosis is unknown. A simple physiologic explanation relates PS to the propulsion of milk curds against the pyloric canal (Lynn, 1960). This explanation seems to be supported by observations of Benson and Lloyd (1964) on 1,120 cases of PS. The genetic transmission of PS is manifested by the male predominance in the population of infants affected by PS, and by the increased incidence of this condition in children of affected parents. PS developed in about 19% of the sons and 7% of the daughters of females who had PS (Carter & Evans, 1969).

The time period through which the infants suffered from starvation in many cases matches the critical periods in development of anxiety proposed by Benjamin (1965). The latter suggests that at birth a "passive barrier" is present "due to lack of functioning connections". Having found that at the age of three to four weeks normal infants show a marked increase of sensitivity to external and internal stimulation, an increase corroborated by EEG changes, he concluded that this indicates the overcoming of the "passive barrier". He further proposed that an "active barrier" develops as early as eight to ten weeks and matures rapidly thereafter, making it possible for the older infant and young child to protect themselves from excessive stimulation by active efforts. He regarded the period between three to four weeks and eight to ten weeks as one of heightened vulnerability, when the infant is in special need of maternal protection against stimuli.

Benjamin advances the hypothesis that the mother's failure to meet this need adequately might have contributed to a heightened predisposition to anxiety. This applied to the present study in which starvation was caused by the medical condition of Pyloric Stenosis (PS), against which the mother was helpless. (According to clinical observations many PS infants "look anxious").

In summary, the following speculation might be formulated on the basis of the presented literature: starvation may affect the child's early cognitive development by damaging the brain, lowering his attentiveness to stimuli, and by increasing anxiety. The irreversibility of these effects on later learning abilities has not yet been demonstrated. If any of these effects are long lasting they may lower the child's intellectual performance and learning abilities.

Research Advantages in the Study of Pyloric Stenosis

Cause and effect relationships can best be demonstrated in experimental studies. However, since there are obviously no experimental manipulations involved in studying the effects of starvation on human subjects, the only kinds of studies possible are field surveys, which usually yield only correlational data between variables, and can approximate a cause and effect relationship only by successive examination of several plausible "causes", through the use of comparison groups. The lack of appropriate comparison groups is the main difficulty apparent in all the human studies reported on this subject to date.

One of the major difficulties in the interpretation of the findings in most of the human studies stems from the fact that starvation and low socioeconomic conditions seem to go hand in hand making it difficult to separate the effects of each on later intellectual functioning. In addition, data on the exact date of onset, duration and severity of nutritional deprivation, were lacking. Since most of the children stay in the same environmental conditions into which they are born, early effects of malnutrition cannot be separated from later effects; thus, only speculations can be made about effects of starvation in the early "critical period" on the development of later cognitive abilities.

Most of the research difficulties presented above can be overcome under conditions presented by a naturally caused type of infant starvation, Pyloric Stenosis (PS):

(a) PS occurs in early infancy at a period when the brain is growing very rapidly and starvation may have significant irreversible effects.

(b) PS does not seem to be related to the socioeconomic status of the family. The infant's starvation is not caused by poverty or neglect, making it possible to isolate malnutrition from other environmental effects.

(c) Following treatment (a relatively minor operation), the child recovers and "malnutrition" ceases, unlike other conditions studied, in which the period of malnutrition is undefined or prolonged.

(d) Severity of starvation can be determined by measures such as weight loss and duration of starvation.

In summary, a defined period of starvation in early infancy, unassociated with social deprivation or poverty is a condition rarely found in cases other than PS, and thus unusually favorable for research.

A Previous Attempt To Study The Effects of PS On Mental Abilities

The present study is not the first to look at Pyloric Stenosis in an attempt to determine the effect of early malnutrition in humans on their later development and behavior. Berglund and Rabo (1973) conducted a follow-up study of 180 Swedish boys who suffered from Hypertrophic Pyloric Stenosis during the period 1922 through 1942. The disease in these patients started between the ages of 6 to 20 days. Following treatment of varying duration they resumed normal food intake as compared to that of randomly selected Swedish children. Data on these subjects was gathered from military service records. Subjects were divided into four groups on the basis of severity of starvation suffered in infancy. To evaluate the severity of starvation, the weight deficit at the time the child attained his minimum weight was calculated as a percent of predicted weight that the child ought to have had at that time based on his birth weight.

According to this index of severity, subjects were divided into the following groups: Group I included 56 patients whose weight never dropped below birth weight; Group II included 57 patients who suffered a moderate weight loss for a short duration; Group III included 44 patients with moderate inanition; Group IV included 23 patients who suffered a severe inanition and weight deficit.

Each subject was interviewed and his height and weight recorded. Scores on an unidentified intelligence test at registration for military service were used as a measure of his mental abilities. The above test has been given to all military recruits since 1943, so data are lacking for patients born before 1925. The results of this test for each year are adjusted to a mean value of 5.0 with a distribution from 1 to 9. In addition to the intelligence test, the subjects passed a military adaptation test, which included certain personality and social measures. Results indicated that the mean adult height for the subjects decreased with increasing severity of starvation. The mean for Group II was 177.2 cm; for Group III, 176.1 cm; for Group IV, 173.3 cm. Of 88 subjects who had siblings, only 15 were taller than their brothers. The intelligence test as well as the adaptability test demonstrated a slight decrease in the numeric values with each level of severity of starvation. These differences were not statistically significant. An unexpected finding in this study was the low fertility in the group who suffered from severe starvation.

Berglund and Rabo's study attempted to look into several of the questions which are examined in the present study. Their measures of intelligence and adaptation were crude measures not yielding information as to possible deficits in specific intellectual abilities.

The subjects in Berglund and Rabo's study were not operated on for Pyloric Stenosis and thus did not experience a sharp termination of the starvation. All patients had the same type of treatment, numerous small feedings by spoon, spasmolytics and in some cases subcutaneous salt solution with glucose. Fifteen patients had died and thus no data were collected on them. It is reasonable to assume that these patients had suffered from the most severe starvation compared to the other subjects, and thus might have revealed more significant deficits in intellectual abilities. Berglund and Rabo did not attempt to examine the possible relationship between the time of starvation onset and the severity or type of deficit in later intellectual development.

In summary, Berglund and Rabo's study does indicate a definite effect of starvation on physical growth and suggests a trend toward an effect of starvation on intellectual abilities and "adaptation". The limitations of Berglund and Rabo's study suggested the need for further investigation of the type presented here.

General Design of the Study

On the basis of the studies reported here, it is safe to assume that differences in severity and in time of starvation onset will determine the extent of the brain impairment or behavior modification and consequently its effect on learning abilities. The aim of this study is to describe the effects of brief and defined periods of starvation in early infancy on subsequent learning abilities.

In order to approach the goal of isolating starvation in infancy as the assumed cause of subsequent deficits in learning abilities, the present study was designed to include the following two parts:

Part 1: A comparison of children with PS (the index cases) and two other groups, one composed of siblings, the other of matched control subjects. The sibling comparison group was designed to control for the genetic factors involved in PS as well as for the home environment, both of which could have had an effect on learning abilities independent of starvation. The matched control group made it possible to compare the score of each index case to the score of another child of the same age, sex and level of parental education from the general population of children in Monroe County, New York.

Part 2: A within group comparison involving the group of index cases only. This part of the study dealt with the relationship between the degree and time of onset of starvation and their quantitative and qualitative effects on learning abilities. In this comparison the factors related to hospitalization and operation were controlled for, since all subjects involved in this part of the study had undergone the hospitalization and operation for PS.

Hypotheses

Since the study is composed of two parts, there are two corresponding sets of hypotheses:

1. Intergroup comparisons

Hypotheses dealing with the comparison between the index cases, their siblings and the matched control subjects:

A. The standard scores of the index cases on all tests of learning abilities are lower than those of the siblings and of the matched control subjects.

B. Index cases have higher factor scores on Immaturity, Overactivity, Conduct problems and Personality problems (derived from the Ottawa School Behavior Checklist), and lower scores on the Vineland Social Maturity Scale, and the Parental Estimate of Development Scale, as compared to their siblings and the matched control group.

2. Intragroup comparisons

Hypotheses dealing with comparisons between index cases who experienced starvation of different degrees of severity and at different periods of time in infancy:

C. The severity of starvation experienced by the index cases is negatively related to their standard test scores.

D. There are differences in standard test scores between subjects who suffered from starvation at different periods of time in infancy.

E. For each learning ability assessed, there is an interaction between the time of onset and the severity of starvation, resulting in lower scores with greater severity of starvation for certain periods of starvation onset.

F. There are differences in the scores of Immaturity, Overactivity, Conduct problems and Personality problems between subjects who suffered from starvation at different periods of time in infancy.

G. Subjects who suffered from severe starvation have higher factor scores on the OSBCL and lower scores on the VSMS as compared to subjects who suffered from "milder" starvation.

H. For each of the behavior problem factors assessed there is an interaction between the time of onset and the severity of starvation, resulting in higher scores with greater severity of starvation for certain periods of starvation onset.

Subjects

A total of 144 subjects in the following 3 groups participated in this study: 1. index cases; 2. sibling comparison group, and 3. matched comparison group. Each of these groups is described in the succeeding section.

Identification and Selection of Subjects

Selection of the Index Cases and Siblings

At the request of Dr. Gilbert B. Forbes and Dr. Philip R. Nader, three hospitals in Rochester, New York, Strong

Memorial Hospital, Rochester General Hospital and Genesee Hospital, submitted a list of all patients who were operated on for PS between the years 1959 and 1968 (i.e. children who were between 5 and 14 years old in Spring, 1973). This list included the names, hospital record numbers and dates of birth of 200 children, out of a total population of 350 children from Monroe County, New York, operated on for PS in the above hospitals up till 1973.

Hospital records of these 200 children were pulled out by the hospitals, and the following information from each record collected: Name of child's father, mother, and address at the time of the operation. No further additional information was collected at that point to avoid any bias before the testing of the children.

The Monroe County Directory as well as the local telephone book were used to search for the present address of the potential subjects. Out of the 200 potential subjects, 98 were identified as still living in the city of Rochester or its suburbs.

Following the identification process a letter was sent to the parents of each of the identified subjects, who were asked to cooperate by participating in this study, which was described as a study of the long-term effects of PS with a special focus on learning abilities (see Appendix 1). The letters indicated that the results of testing would be made available to them on request. The letters included a conset form to be filled out and signed by the parents giving permission for their children to participate in this study and allowing the investigator to collect relevant data from the child's school. The parents were asked to mail this form to the investigator. The investigator's telephone number appeared in the letter in case any of the parents needed further clarifications about this study. Those parents who agreed for their children to participate in this study were contacted (telephone call) by the investigator for the purpose of setting up an appointment for the PS child, his sibling and parent to come to the office of School Health Program, the University of Rochester School of Medicine and Dentistry.

Fifty-nine families (i.e. 57.3 percent of all the families contacted) expressed their interest in participating in the study.

Based on the medical records of the index cases examined by Dr. Gilbert B. Forbes and Dr. Philip R. Nader, 9 index cases were excluded from the study because of several factors known to be related to damage in the central nervous system, which might have an effect on learning abilities independent of PS. These 9 index cases were excluded for the following reasons: (1) Very low or very high birth weights, below 2.3 kg or above 4.1 kg for boys and 4.3 kg for girls; (2) One girl was excluded because her mother had rubella during the second half of pregnancy; (3) One child was excluded because he suffered from lack of oxygen at birth and was placed in an oxygen tank for several days; (4) Three children were excluded because of a history of convulsions. The same criteria were applied to the sibling group. After the parental interviews, through which information about the siblings was obtained, 2 siblings had to be excluded. Three index cases did not have a sibling and one had an adult sibling that could not be tested.

In summary, the group of index cased included 50 subjects, 44 boys and 6 girls, who had been treated for PS in infancy. The index cases were between 5 and 15 years old with a mean age of 9 years 2 months. The sibling group included 44 subjects, 28 boys and 16 girls, each of whom was a sibling of an index case. Their ages ranged between 5 and 15 years, with a mean age of 10 years 1 month. All were white children.

Selection of the Matched Comparison Group

One matched comparison was chosen for each index case. The matching was done for age (within ± 6 months), sex, and father's education (in years). The matched comparison group was selected from the population of the 1972 Rochester Child Health Study at the University of Rochester Medical School(1). A total of 521 families and 6,669 individuals participated in the study and represented a random sample of the population of the County of Monroe. For each index child several potential matched controls were selected by computer. Three of those with the date of birth closest to that of the index case were selected. In cases for which the computer selected 3 or less matches all the selected matches were contacted. In cases in which more than one control subject agreed to participate, the one whose date of birth was closest to that of the index cases was selected.

Letters were sent to the parents of each child in the matched control group. These letters explained to the parents that this study aimed to investigate how children learn and that the testing done in this study will yield a profile of the child's learning abilities. It was also indicated that this information would be given to the parents on request (see Appendix 2). In order to obtain 50 positive replies, letters were sent to 145 parents of the potential matched controls. Of all the parents contacted in this group, 29 percent expressed willingness to participate in the study. The procedure following the initial contact with the parents was the same for the index cases, siblings and matched control subjects and thus, will not be repeated here.

Following the rules that were applied to the group of index cases, three subjects from the matched control group were excluded from the study, two because of low birth weight and breathing complications after delivery, and one because of convulsions. Three other subjects were chosen to replace the excluded ones.

Comparison Between the Subject Groups

In addition to the variables involved in the selection of the subjects, the index cases, siblings and matched controls were compared on the following variables: duration of pregnancy, mother's age at delivery, birth weight, birth order, number of siblings, and number of operations, other than for PS, in the child's history. Since all the values of t presented in Table 1 do not reach the .05 level of significance, it may be concluded that the index cases did not differ from their siblings and matched controls with regard to any of the above variables except number of operations in the subject's history. Of the index cases, 21 as compared to 13 of their siblings and 16 of the matched controls had an operation (mostly for hernia or tonsils). The differences between the frequencies of operations for each subject group were also found to be insignificant ($\chi^2 = 1.852$, df = 2, $p > .50$).

In summary, it can be stated that the index cases, siblings and matched controls did not differ significantly with respect to any of the variables considered above.

Complications during pregnancy and delivery, as well as acute illnesses or injuries in the subjects' lives, were considered by Dr. Nader and Dr. Forbes, as indicated in the previous sections of this chapter. Several subjects were excluded from the study because of medical conditions known to be associated with deficits in intellectual functioning.

Instruments

The techniques and instruments used in this study were chosen to measure a wide spectrum of intellectual and social abilities that represent human learning abilities, especially

TABLE 1

Means, Standard Deviations, and *t* Values Comparing
Index Cases with Siblings and Matched Controls
on Five Variables

Name of variable		Index cases (N=50)	Siblings (N=44)	Matched Controls N=50
Duration of pregnancy (in weeks)	$\overline{X}$	39.80	39.86	39.82
	SD	1.52	1.21	1.06
	t		.26	.31
Mother's age	$\overline{X}$	27.64	27.48	27.16
	SD	5.29	4.45	3.53
	t		.16	.53
Birth weight (in kg.)	$\overline{X}$	3.39	3.36	3.36
	SD	.41	.27	.27
	t		.33	.39
Birth order	$\overline{X}$	2.66	2.46	2.26
	SD	1.84	1.57	1.48
	t		.58	1.20
No. of siblings	$\overline{X}$	3.12	3.27	2.78
	SD	1.69	1.63	1.36
	t		.44	1.11

those essential for "school learning". The widely used term "learning" is here referred to as a collection of all the schemata, the concepts and mental skills which the individual has acquired up to the present time for coping with problems and which he can apply to the acquisition of further skills and concepts (Vernon, 1968).

The child's learning abilities in this study were assessed through the following procedures:

a. Psychological testing of the subjects.

b. Parental interview and questionnaires.

c. Teachers' evaluation of subjects' behavior.

d. Measurements of the subjects' physical growth including height, weight, and head circumference.

Psychological Tests

The instruments chosen represent activities that encompass skills involving visual and auditory input, different modes of output such as verbal and motor, as well as different levels of thinking such as concrete and abstract. Each of the instruments chosen was standardized for use with children of a wide age range. Testing time for each child was planned not to exceed 1 1/2 hours. No single standard psychological test seemed to answer all the above requirements. Thus, the test battery used in this study has been constructed of different tests and school subtests. One of the major advantages in using a single test battery over a number of different tests is that all subtests are standardized on the same population, making comparisons of scores on different subtests more meaningful. This advantage has been deliberately sacrificed, for the benefit of the other requirements mentioned above.

Theoretical Considerations for the Construction of the Test Battery

Aside from the considerations of validity, reliability and time requirement of each chosen test, the appropriateness of these tests for the subjects' age, there were two major requirements that the chosen psychological tests had to meet:

1. In order to answer the basic question "Does starvation in infancy have an effect on learning abilities?", the tests had to measure those abilities that are essential for a child's success in learning. In other words, the chosen tests had to measure those abilities that, if impaired, would cause learning disorders.
2. In order to allow for a comparison of the findings in this study to data collected in other studies, the tests had to measure those abilities that have been found in previous studies to be affected by starvation in infancy, i.e. a measure of general mental ability, vocabulary and skills requiring intersensory integration.

The traditional intelligence test which yields a single estimate of ability has been heavily criticized in recent years. Most relevant to our discussion is Kirk's (1968) criticism pointing out that both normal and handicapped children do not fit into neat, well-defined categories with uniform characteristics. Children within the same IQ range are not homogenous in their abilities. A battery of tests measuring different abilities has been preferred over a test yielding a single estimate of IQ. Thus, the choice of the battery of tests used in this study was based on the theoretical model of what constitutes a learning disability and on the clinical model from which the ITPA was generated. The ITPA (Illinois Test of Psycholinguistic Abilities or ITPA (Kirk, McCarthy and Kirk, 1968) could have answered most of the requirements stated above. This test was not chosen mainly because it could only be used with children up to 10 years of age whereas the subjects in this study were up to 14 years of age.

In the search for measures of the abilities essential for "good learning", it is instructive to consider those abilities that, if impaired, are known to cause learning disabilities. What is a learning disability? Kirk (1968) defines it as "a specific retardation or disorder in one or more of the processes of speech, language, perception, behavior, reading, spelling, writing, or arithmetic. The word 'specific' is very important in this definition since it implies that the child has a definite retardation in one or more areas but that this retardation is at variance with certain assets" (Kirk, 1968, p. 398). Kirk warns of the danger in categorizing disorders in children; however, for the purpose of clarity, he groups learning disorders under three rubrics: (a) academic disorders, i.e. disorders in reading and arithmetic; (b) nonsymbolic disorders, inability to recognize, discriminate, or automatically integrate sense impressions; (c) symbolic disorders, disability in reception or expression of symbols and ideas. As Kirk indicates in making this distinction between the three types of disorders, it should be recognized that one type of disorder may be basic to another. The battery of tests chosen for the present study represents academic and symbolic abilities and may thus serve as a screening device for disorders in these areas of functioning. No tests for nonsymbolic disorders were found other than in the ITPA, and since the ITPA could not be used for reasons mentioned before, these abilities were not tested.

The ITPA is widely used to analyze the causes underlining learning disorders.

The clinical model from which the ITPA was generated includes the following three dimensions: (a) channels of communication; (b) psycholinguistic processes; and (c) levels of organization. Dimension (a) deals with the channels or routes through which communication flows. The tests chosen in this study represent activities that involve visual and auditory skills, (the two sensory channels most often used in teaching and communication). Dimension (b), the psycholinguistic processes, refers to the three steps of decoding, association, and encoding i.e. the act of obtaining meaning from sensory stimuli, associating it internally with other linguistic symbols and finally expressing an idea in words or gestures. Many of the available psychological tests involve these three steps of decoding, association, and encoding. An attempt was made in this study to choose tests that represent different conbinations of decoding and encoding, i.e. decoding of visual information and motor encoding, or decoding of auditory information and vocal or verbal encoding. Dimension (c) deals with two different levels of organization automatic/sequential and representational. The first level deals with activities requiring the retention of visual or auditory sequences and automatic habit chains. The representational level encompasses activities using the meaning or significance of symbols. The chosen tests for this study represent both of the above levels of organization. Table 2 presents the correspondence of the tests used in this study to the dimensions of the clinical model of the ITPA.

We will turn now to the presentation of the chosen instruments and some indications of their reliability and validity. Unless otherwise indicated, the reliabilities and validities reported for each test were based on information given in the test manual.

Verbal skills have been found in several previous studies to be severely affected by starvation. These skills are es-

TABLE 2

Learning Ability Tests Used in this Study in Correspondence to the Dimensions of the Clinical Model of the ITPA

	Channels of communication				Levels of organization	
	Input		Output			
	Auditory verbal	Visual	Auditory-verbal	Visual motor	Representational	Automatic
PPVT	+	+		+*	+	
Vocabulary	+		+		+	
Coding		+		+		+
Auditory Mem. Forward	+		+			+
Auditory Mem. Backward	+		+		+	
Visual Memory		+		+		+
Raven		+			+	
Reading		+	+		+	
Arithmetic		+		+	+	

*The subject may point to the answer he chooses or name his choice by number.

sential to thinking and central in the reception and communication of ideas. As such, verbal skills were measured in this study by two tests: The Peabody Picture Vocabulary Test and the Vocabulary Test from the Wechsler Intelligence Scale for Children.

Peabody Picture Vocabulary Test (PPVT, Dunn, 1965)

The PPVT was designed to provide an estimate of a subject's verbal intelligence (IQ) through measuring his hearing vocabulary (Dunn, 1965). On this test the subject is asked to choose from among four illustrations the one that best shows the meaning of the stimulus word spoken by the examiner. Besides being effective with average subjects, the PPVT has special value with certain other groups. Since subjects are not required to give an oral response, this test is especially appropriate for speech-impaired, non-readers and remedial reading cases. It also has advantages with certain autistic or withdrawn persons by reducing the tensions of the testing situation due to the nature of the task requirements. The graphic illustrations of the possible answers are free of fine detail and figure-ground problems, to eliminate at least some of the special difficulties of perceptually impaired persons. the PPVT is given in 10 to 15 minutes. It is, however completely untimed and thus is a power rather than a speed test.

The PPVT was standardized on 4,012 subjects from 2 years 6 months to 18 years. Alternate-form reliability coefficients ranged from .84 to .67 with a median of .77. The median correlation of the PPVT with the Stanford-Binet was .71 and with the WISC scale .61.

On the PPVT the subject is asked to decode an auditory symbolic stimulus and recognize the visual stimulus that is best associated with it. The PPVT tests understanding of the meanings of words without calling for a verbal communication of this understanding.

Vocabulary Test from the Weschler Intelligence Scale for Children (WISC; Wechsler, 1949)

To complement the PPVT, the Vocabulary test from the WISC was chosen. On this test the subject is required to give an oral definition of a list of words read by the examiner.

Most of the words in the list can be scored 2, 1 or 0. While elegance of expression is disregarded, poverty of content is penalized. This test requires decoding of auditory symbolic stimuli and oral symbol encoding of the answers. Unlike the PPVT which requires recognition of the right answers, the vocabulary test on the WISC requires recall. The level of association of what is recalled is evaluated through the scoring of its content. The WISC was standardized on a sample of 100 boys and 100 girls at each age level from 5 through 15 years. There were 1100 boys and 1100 girls in 11 age groups, a total of 2200 cases. Sampling was done for geographic location, urban/rural residency and parental education. The average reliability of this test is .86 calculated for a sample of 100 boys and 100 girls within each age level between 7 years 6 months and 13 years, 6 months. The correlation coefficient between the full scale verbal score and the vocabulary score is .79 for 100 boys and 100 girls 7 years 6 months old, .89 for 100 boys and 100 girls 10 years 6 months old, and .84 for 100 boys and 100 girls 13 years 6 months old. The correlation between the vocabulary scores and the full scale score on the WISC for each of the three age groups mentioned above is respectively .71, .87, and .78.

Coding Test from the WISC (Wechsler, 1949)

On this test the child is presented with a code for each pattern or number. He is then required to respond to a certain visual stimulus by writing the appropriate coded sign for it in the designated space as fast as he can. This test measures speed and accuracy of learning to associate meaningless signs with meaningful symbols, it involves skills related to spatial perception, immediate visual memory and motor control. The Coding test presents a good opportunity to observe the child's behavior in situations requiring time limits. Since this test involves visual decoding and motor encoding, it may serve as an estimate of visual motor coordination. In the vocabulary tests discussed previously, the child was tested for knowledge of words that he had acquired in the past i.e. "old learning", on the Coding test he is being tested for learning a new code i.e. "new learning". The same sample of 1200 children mentioned before in discussing the standardization of the Vocabulary test was used for the Coding test. The average reliability of the Coding test is .74 (Rhodes, 1969). The correlation of this test with the total performance score on the WISC ranges from .53 to .32 for the different age groups.

Auditory Memory, (Digit Span Test) from the WISC (Wechsler, 1949)

The test includes two tasks. The first task requires the subjects to repeat series of digits read to them at a rate of one digit per second. The second task requires the subjects to reconstruct the series of digits read to them in reverse order. This task involves attention, concentration, sequential rote memory and memory restructuring (memory for the reversed sequence). Heriot's (1973) findings suggested that the memory/attention dimension is most significant in the etiology of learning disorders. In a study of 341 children referred for learning difficulties, 53% of the children who had difficulties in reading or arithmetic had difficulties in auditory rote memory as measured by the Digit Span test, and 78% had difficulties in auditory rote memory and memory restructuring measured by the same test. The Digit Span test involves auditory-verbal encoding and decoding. The two tasks in this test require two different association levels, rote memory for the first and rote memory plus memory restructuring for the second. The average test-retest reliability for the

Digit Span test is .56 and the correlation between scores on this test and total performance scores on the WISC is .72 (Rhodes, 1969).

The Visual Memory Test from the Hiskey-Nebraska Test of Learning Aptitude (H-NTLA; Hiskey, 1966).

The Digit Span test measures memory for stimuli presented auditorily. The Visual Memory tests measure sequential rote memory for visually presented stimuli (colors and digits). The test materials consist of colored plastic stripes for subjects up to age 10, and of plastic digits for subjects who are 10 years old or older. On the Visual Memory Test for Colors, the subject is presented briefly with colored plastic stripes arranged in a specific order, and is required to reconstruct an identical array from memory. On the Memory for Digits test the child is presented briefly with a number of digits printed on a card and is required to reconstruct from memory these numbers using plastic digits. The memory for colored stripes and the memory for digits, although testing memory for visually presented stimuli, involve two different types of tasks. The Visual Memory for Colors calls for memory of nonsymbolic stimuli, whereas the Memory for Digits requires memory for symbolic stimuli. A matched comparison between scores on one of the above two types of visual memory and the other is avoided by comparing only test scores of subjects who are of the same age, i.e., for whom the visual memory is tested by the same type of materials. Thus, for scores on the Visual Memory tests, a matched comparison between test scores of the index cases and their siblings, was not carried out. The scores of the index cases and their matched controls were compared. Despite this problem, the Visual Memory test from the H-NTLA was chosen because of the unavailability of any other test measuring this ability in children between 5 and 14 years of age.

The H-NTLA was standardized separately upon deaf and hearing children. Over 1100 hearing children between the ages of 2 years 6 months and 17 years 5 months were tested. The children came from 10 widely separated states.

Since this scale consists of separately scored parts or subtests, the correlations between the subtests are important. Correlations were obtained between the age ratings on each subtest and the median age ratings on the total test. These correlations varied from a low of .514 to a high of .889 and gave evidence to the internal consistency of the scale. Selected samples showed correlations with the Stanford-Binet of .86 for hearing children 3 to 10 years of age and .78 for hearing children 11 to 17. A correlation of .82 was obtained when hearing children's ratings on the entire H-NTLA were compared with their ratings on the WISC.

The correlations between the scores on the visual memory tests and the score on the entire H-NTLA is .621 for 614 children 3 to 10 years old, and .635 for 460 children 11 to 17 years old.

Raven Progressive Matrices (PM; Raven, 1956, 1958)

This test was chosen as a nonverbal measure of the ability to analyze a visual perceptual field and understand the logical rules governing the relationship between its parts. The subject is asked to choose among 6 or 8 suggested answers the one that best completes a missing part in the pattern i.e. best agrees with the rules governing the organization of the test pattern. This is a power test rather than a speed test. For subjects up to age 11, the Colored Progressive Matrices were used. For subjects over 11, the Standard Progressive Matrices were used. One hundred children of each year of age from 5 to 11 1/2 served as subjects for the standardization of the Colored Progressive Matrices. These children were drawn from among 2700 children in the borough of Dumfries whose names began with the letter E to L inclusive. The average internal consistency of the test for all ages lies between 0.74 to 0.97. Test-retest reliability for 58 children 6 1/2 ± 1 year was 0.6 ± 0.06 and for 61 children 9 1/2 years ± 1 year was 0.8 ± 0.03 (Raven, 1965). The relatively low retest reliability at 6 1/2 years of age as compared with the test-retest reliability at 9 1/2 years may be attributed to the scale's sensitivity to fluctuations in the output of intellectual activity in early childhood rather than to any defect in the scale itself. Several studies of concurrent validity have related the Standard Progressive Matrices (PM) to individual and group tests of mental ability ranging from the high 40's to the mid 80's (Giles, 1964). A correlation of .63 was found between the PM and the Differential Aptitude Test: Abstract Reasoning, Form A, for 130 junior high school children. For these same subjects a correlation of .56 was found between the PM and SRA High School Placement Test: Pictorial Reasoning (Giles, 1964).

The Wide Range Achievement Test (WRAT: Jastak & Jastak, 1965)

Most of the children who have learning disorders have difficulties in reading and arithmetic. Following the examination of several specific learning abilities it was found necessary to measure the subject's ability to integrate and coordinate their learning abilities in a way that will allow them to reach satisfactory levels of achievement for their age in reading and arithmetic. The WRAT has been found valuable in several areas of knowledge and their practical applications, of which the following are of special interest in the present study: (1) The accurate diagnosis of reading and arithmetic disabilities in persons of all ages; (2) The study of the degree and nature of loss of reading and arithmetic ability as a result of brain injury and other physical disturbances. On the reading test the testee, depending on his age, is required to recognize and name the letters of the alphabet and read words of increasing difficulty. The words are presented in isolation i.e. not in a context of a sentence. The arithmetic test includes an oral and a written part. The oral part is aimed at assessing some basic abilities to deal with numbers (counting, recognition of numbers and "which is more"). The written part of the arithmetic test presents calculation exercises of varying degrees of complexity. This test is both a power and a speed test. The standardization of the WRAT Level I was done on a total of 5,868 subjects ranging from 5 years to 15 years old and including a group of adults. Each 6 months of age were represented by approximately 150 males and 150 females. Standardization of Level II of the WRAT involved 5,933 subjects between the ages of 9 to 25 years of age including a group of adults up to 65 years old. The subjects represented a number of states in the U.S. The reliability of the WRAT was studied for 200 children in each age group between 5 and 20 years old. Split-half correlation coefficients for the raw scores on the Reading test ranged from .981 to .993 and for the Arithmetic test from .942 to .970. Scores on the Reading test correlated .88 with mid-term grades of the testees and .84 with their score on the New Standard Word Reading test. The correlation of the WRAT Arithmetic test scores with the scores on the New Stanford Arithmetic for 170 children was found to be .91. In summary, the WRAT is a well standardized, reliable, and valid measure of achievement in reading and arithmetic.

Parental Interviews and Scales

The following two basic considerations led to the inclusion of parental interviews and scales in this study:

1. To complete the profile of the child's learning abilities measured in the present study by the chosen psychological tests. Parents differ with regard to their ability to evaluate their normal children. They are, however, more objective when asked about their children's specific problems in learning, social adjustment, motor coordination or personality.

2. To study events in the child's developmental history including pregnancy, birth, early motor, verbal and social development, possible traumas or injuries, medical history of the child and his family. This information was used for the construction of frequency distributions in an attempt to evaluate whether other factors besides Pyloric Stenosis could have had an effect on the learning abilities measured in the present study. In other words, the information gathered through the parental interviews was used to examine whether any differences found between the subject groups could have been associated with any other factor more frequently present in one of the subject groups as compared to the others. The parental interviews were conducted according to a uniform interview outline that included questions touching upon every one of the aspects mentioned above (Appendix 3). Parents of the index cases were told that information about their child's Pyloric Stenosis is found in the hospital records and thus there was no need for obtaining this information from them in

the interview. This was done to reduce experimental bias toward the subjects. To increase the validity of the information gathered from the parents, they were asked to estimate their children on the two following scales:

Parental Estimate of Development Scale (PEDS, Heriot, 1972)

This scale was developed at the Psychodiagnostic Laboratory of the University of Rochester School of Medicine and Dentistry (Heriot, 1972; Appendix 4). Parents responding to this scale are asked to rate their children on the following four dimensions: mental age, intellectual level, potential occupational level, and potential educational level. Each subscale can be converted to mental age (MA) and IQ equivalents. The four subscales can be averaged to yield an overall parental estimate. The PEDS can be compared to the child's general level of functioning as well as to his specific strengths and weaknesses. This scale was studied on a sample of 54 subjects and parents. The mean age of the subjects was 63.22 months with a range of 18 months, the mean IQ of these children was 101 with a standard deviation of 11.38. Each subject was tested three times in fall, winter, and spring. PEDS ratings were obtained during all three testing sessions as well as from the pretesting during which the PEDS was mailed in by the parents. The mean PEDS was found to be 3.5 IQ points above the subject's measured IQ. Test-retest reliability for the PEDS was found to be .95. Rosenthal and Jacobson (1968) highlight the utility of scales such as the

PEDS in diagnosing some of the parameters of academic underachievement.

Vineland Social Maturity Scales (VSMS, Doll, 1965)

This scale provides a list of the detailed performances in which children show a progressive capacity for looking after themselves and for participating in those activities which lead toward ultimate independence as adults. Each item is read to the parent and he is asked whether his child usually or habitually does the activity. The items of the scale are arranged in order of increasing difficulty and represent progressive maturation in self-help, self-direction, locomotion, occupation, communication and social relations. Each item on the scale is conceived as representing a general growth in social responsibility which is expressed in some detailed performance as an overt expression of that responsibility. This scale affords: (a) a standard schedule of normal social development; (b) a measure of individual differences. Standardization data have been obtained for ten normal subjects of each sex at each year from birth to thirty years of age, or a total of 620 subjects. This is not a sufficient number of subjects for final standardization, but it may be noted that the calibration of such a scale is not determined by the number of subjects at any one age alone, but rather by the succession of ages over a range of years. The stability of such standardization is therefore determined in a large measure by the internal consistency of the scale as a whole (Doll, 1965).

Teacher's Evaluation of Subject's Behavior

The Ottawa School Behavior Checklist (OSBCL, Pimm and McClure, 1969) (Appendix 5) was chosen to measure the teacher's evaluation of the child's behavior in school. The OSBCL is composed of 100 statements describing behavior of children in school. The teacher is asked to check the "yes" column corresponding to a described behavior if the child in question does show that behavior and the "no" column if the child does not manifest that particular behavior.

This scale calls for objective rather than subjective evaluation of each child and may be used for children in different schools and of different ages. The checklist was based on the study of 1,445 children and 62 teachers; 20 of the items differentiated between a group of "emotionally disturbed" and "normal" children as defined by teachers' observations based on factor-analytically defined concepts. This test checklist was also found to have predictive validity with regard to behavioral disorders for a group of 128 children over a four-year period. The behaviors listed in the OSBCL have been factor analyzed into the following factors: immaturity, over-activity, conduct problems, and personality problems. The OSBCL yields scores for each of these factors. Since the present study was carried out close to the end of the school year, each of the teachers participating in the study had known the child he was asked to evaluate for at least one academic year.

Procedures

The procedures required for the intergroup and intragroup analyses in parts I and II of this study included the following five steps:

1. Identification of subjects.
2. Contacting parents and setting up appointments.

3a. Psychological testing and physical measurements of the subjects, parental interviews and collecting information from teachers.

3b. Examination of the hospital medical records of the index cases.

4. Summary of data collected in step 3a.
5. Introduction of data collected in step 3b and statistical analysis of the data.

Steps 1 and 2, starting with the identification of the subjects and ending with setting up appointments for them, were described in this chapter under the title "Subjects", and thus will not be discussed again here. Parts a and b of step 3 proceeded simultaneously but independently, i.e. Dr. Nader and Dr. Forbes examined the medical records of the index cases while the investigator and the testers examined the subjects and interviewed the parents. This type of procedure was planned in order to avoid any form of bias in the testing that could have possibly arisen from the investigator's knowledge of the degree of severity or time of onset of starvation for each index case.

In order to allow for comparison between the test results of the different groups of subjects, conditions of testing were kept constant for all subjects. In an ideal experimental situation this would mean testing all subjects at the same time in the same place by the same tester. These conditions were obviously not realistic and thus several of the variables involved in the testing were controlled by being kept constant and others by randomization.

Place: All subjects and their parents were seen in special quarters arranged for this study at the School Health Program, 1545 Mt. Hope Avenue, Rochester, New York.

Each index case and his sibling were tested at the same time in order to avoid: (1) doubling the time the parents and children had to spend in the clinic, and (2) to avoid any possible exchange of information about the tests between the siblings.

Since the index cases and their siblings were tested simultaneously, the testing took place in two adjacent soundproof rooms. A desk and two chairs were the only furniture in each of the two rooms. Any other possible distractions of the child's attention such as wall decorations or designs on curtains, were kept at a minimum.

Testers: Since one person could not simultaneously test two children, and in order to limit the effects of the tester's personality on the testee's performance, subjects were randomly assigned to three psychometricians. (The study started with four psychometricians, however, one of them had to leave town shortly after the testing period started.)

The testers were all white females ranging in age from 27 to 35 years with a mean age of 31. All of them were graduates of a special masters program in learning disorders and trained in psychoeducational testing. Each tester was familiar with the tests used in this study and was observed by the experimenter in several trial testing situations until the administration and scoring of all tests was achieved without any problems.

All subjects were randomly assigned to the testers, which also involved the random assignment of day and time of testing. A maximum of 2 children were tested by each tester in one day to avoid effects of fatigue.

Testing Procedure: In order to reduce the subject's test anxiety, he was reassured by the following statement: "Most of the children that come here find these tests very interesting and I hope that so will you". A brief warm-up period preceded the testing. This period included open questions about the child's name, age, friends, or any other subject each child seemed to feel at ease talking about.

The order of test presentation was based on the type of task involved in each test. The tests were presented to all subjects in the following order: Peabody Picture Vocabulary (PPVT), coding, auditory memory, Progressive Matrices and the Wide Range Achievement Test. The PPVT is considered a good test for establishing rapport with the subject. It calls for interaction between tester and testee but does not limit the testee to one type of response. The test allows the subject to begin by achieving a series of successes in his own preferred cognitive style. Tests measuring tasks of a similar nature such as the two vocabulary tests and the two memory tests were not presented consecutively to limit the effects of fatigue or boredom that might arise from doing one type of task for too long. The Reading and Arithmetic tests were placed last because of their "school like" nature. Most of the subjects had some experiences with reading and arithmetic in school, placing these tests at any other place but the end could have let possible feelings of anxiety and antagonism toward these subjects affect achievement on other tests.

The psychological testing required an average of 1 1/2 hours. Following the psychological testings, each child's height, weight and head circumference were measured. The instrument used for measuring height was a sliding wooden triangle and a measuring stick attached to the wall. The subject was standing on a board with his back to the wall and as close as possible to it. The investigator would then slide the triangle until it rested on the subject's head. The point at which the triangle's base touched the measuring stick was recorded as the subject's height. Weight was measured by a Fairbanks model sliding weight scale. Head circumference was measured three times and the average measure was noted as the child's head circumference.

Information about the parent's height and weight was gathered in the parental interviews.

While their children (or child) were tested, the parents were interviewed by the investigator for an average of 20-30 minutes. Following this interview the Vineland Social Maturity Scale was administered. The parents were then asked to evaluate their children on the Parental Estimate Scale.

The Ottawa School Behavior Checklist together with a stamped envelope addressed to the investigator were handed to the parents. They were asked to speak to the teacher who had most contact with their child and ask her or him to complete the checklist and mail it back to the investigator. The parents were told that upon receiving all the information back from school the results of the testing would be summarized and made available to them.

Step 3b in the procedure involved determining the severity and time of onset of starvation in infancy. Dr. Gilbert Forbes and Dr. Philip Nader examined the medical records of the index cases. The degree of undernutrition (severity of starvation) was evaluated in the following manner: Weight percentile graphs were constructed from the detailed data presented by Heimendinger (1964) on the growth of young infants. The birth weights of our subjects were entered on this graph, and it was assumed that they would have remained in this weight percentile had they not developed Pyloric Stenosis. In this manner the expected weight per age at the time of admission to the hospital could be read from the graph. The weight deficit was then determined by subtracting the actual weight at admission to the hospital from the expected weight, and this deficit was expressed as a percentage of the expected weight.

Time of onset of starvation was measured in days of age and based on the parents' report at the time of the child's admission to the hospital. Other information pertinent to this study was collected from the medical records. Data on problems in pregnancy, delivery and early medical history of each subject and his family were noted. This information was later compared with the information collected through the parental interviews. Decisions were then made about the elimination of some index cases from the study on the basis of medical problems other than the Pyloric Stenosis.

Limitations

Several confounding variables are inherent in the present study. The major methodological problem stems from the fact that 5 to 14 years have elapsed between the period of starvation in infancy and the measurement of the present learning abilities. During that period, different factors on which there is no direct control, could have had an effect on the child's learning abilities. The subject groups were compared with regard to many variables collected from parental interviews and hospital records. These comparisons were carried out to examine the possibility that a factor other than PS was responsible for differences between the groups. However, it was theoretically unrealistic to control for all variables that could have had an effect on the development of each subject.

Another limitation of this study involved the selection of subjects. The index cases in this study were not randomly chosen for the starvation "treatment" (PS). Furthermore, from the population of all those who were operated on for PS in Rochester between 1959 and 1968, only those who were still in Rochester and volunteered to participate were studied. Volunteers may have special characteristics that contaminate the findings. The fact that the matched control subjects were also volunteers corrects at least partially for this limitation.

Although there was an awareness of the methodological limitations of this study, it was proposed due to the significance of the research questions it presented. Attempts were made to account for as many variables as possible in order to achieve the aim of singling out the starvation in infancy as the assumed cause of deficits in learning abilities.

Chapter III

RESULTS

The results presented in this chapter test the hypotheses corresponding to the two parts of the study, i.e. the intergroup comparisons between the index cases, their siblings and matched control subjects, and the intragroup comparisons within the group of the index cases.

The dependent variables in this study were learning abilities of the subjects. These abilities were measured by psychological and educational tests yielding test scores that were expressed in terms of scaled scores. Due to the statistical characteristics of scaled scores, parametric statistics were used in their analyses. In order to test the hypotheses for each learning ability separately, all analyses of test scores were carried out for the scaled scores of each test independently.

Intergroup Comparisons

The intergroup comparisons included testing of hypotheses A and B. These hypotheses deal with the comparison of test scores across the three groups (index cases, siblings, and matched control subjects). Since each index case was paired with one subject in each of the other two groups, the statistical analysis had to account for the fact that the compared samples were dependent. Based on the nature of the data and on the questions posed by the above hypotheses, a two-way analysis of variance for experiments with repeated measures was the first step in the analysis of the results. This method is described by Winer (1962, pp. 306-7). The computer program used for this analysis was ANAVAR 2 which is a main program written in Fortran IV, that performs a two-way analysis of variance for experiments with repeated measures. The dependency between the subjects across the three subject groups was expressed in this analysis as though there were 3 repeated measures on each subject. There were 50 index subjects, 44 siblings and 50 matched control subjects, however, for the purpose of comparing matched individual subjects across the subject groups, those 6 index cases that did not have a sibling participating in the study were excluded from this part of the analysis, their matched comparison subjects were excluded as well. This analysis was carried out for 132 subjects divided into the following 3 groups of 44 subjects each: Index cases, siblings, and matched comparisons. These groups formed the 3 columns in the two-way analysis of variance. The index cases were divided into 3 groups based on the severity of starvation they had experienced in infancy. These groups were as follows: 1) High severity subjects who suffered a weight deficit of 21% and over (N=13); 2) Moderate severity subjects who suffered a weight deficit of 11-20% (N=18); 3) Low severity subjects who suffered a weight deficit of less than 10% or no weight deficit at all (N=13). These groups, plus their siblings and matched controls, formed the 3 rows of the two-way analysis of variance. Theoretically significant differences between the above rows were not expected since the siblings and the matched comparisons were not affected by starvation and their scores on the abilities tested were expected to be normal for their age. Adding the scores of the siblings and matched controls to those of the index cases was expected to sway the mean of the group presented by the row towards the mean score in the normal population, and thus distort the possible differences existing between the index cases in the different levels of starvation. The interaction effect calculated in the two-way analysis of variance for each learning ability was also not expected to be significant.

Analysis of variance answers the question of whether the samples tested are taken from a population with the same mean. If the analysis of variance indicates a significant difference between the means of these samples, the reamining question is which of the samples tested are different. If, on the basis of the analysis of variance, one may conclude that there is a significant difference between the subject groups, what remains to be tested is whether the index cases differ from both their siblings and their matched controls or only from one group and not the other, and whether the matched controls differ from the siblings. For the purpose of these comparisons, _t_ tests for dependent samples were carried out.

In summary, the procedure discussed above followed two steps: analysis of variance to examine whether there were differences between the subject groups, followed by t tests to establish which groups differed from each other. The first step of the analysis follows in Tables 3 to 16, the final step, (the t tests) are summarized in Tables 17 and 18. It should be stressed here that no conclusion with regard to the hypotheses should be made on the basis of the analysis of variance alone. However, the latter are presented in detail to provide a picture of the means and standard deviations of all subjects on the different tests.

Testing of Hypothesis A

Hypothesis A states: The standard test scores of the index cases are lower than those of the siblings and the matched control subjects. This hypothesis was tested for each of the learning ability tests as presented in the following pages.

Peabody Picture Vocabulary Test (PPVT). This test measures the subject's hearing vocabulary, i.e. the ability to identify the meaning of words spoken by the tester. The subject is required to indicate which of four possible picture choices represents the meaning of the word.

Based on the summary of the analysis in Table 4, it may be concluded that the index cases, siblings and matched controls differ significantly in their scores on the PPVT ($p <.05$). No significant difference between the rows nor any interaction effect was found.

TABLE 3

Mean Scores and Standard Deviation of all Subjects on the PPVT

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\overline{X}$	101.31	113.54	114.[illegible]8	109.74
	SD	32.50	10.26	12.32	21.76
Moderate severity	$\overline{X}$	104.94	112.00	113.50	110.15
	SD	18.90	18.65	9.60	16.72
Low severity	$\overline{X}$	111.38	113.62	112.77	112.59
	SD	9.81	11.59	11.65	11.09
Column means & SD	$\overline{X}$	105.77	112.93	113.55	
	SD	22.40	14.62	11.09	

The differences between Standard Deviations in the above table and in the following tables will be discussed on pages 139-141.

TABLE 4

Summary of Two-Way Analysis of Variance for Scores on PPVT

SOURCE	DF	SS	MS	F
Between Subjects	43	16025.42		
Between Rows	2	191.06	95.53	0.247
Subjects Within Rows	41	15834.35	386.20	
Within Subjects	88	22527.33		
Between Columns	2	1643.32	821.66	3.311*
Between Cells	4	533.39	133.35	0.537
Columns x Subjects Within Rows	82	20350.63	248.18	
Total	131	38552.75		

* $p < .05$

Vocabulary Test (From the WISC). This test measures the ability to define or explain single words. The subject hears the test words and is required to give an oral verbal response to each of the words. Tables 5 and 6 present the subject's mean scores on the Vocabulary Test and the summary of the analysis of variance.

Results of the analysis of variance summaried in Table 6 lead to the conclusion that there are significant differences between the index cases, the siblings and the matched controls on the Vocabulary Test ($p < .01$). No significant row effect or interaction effect was found ($p > .05$).

TABLE 5

Mean Scores and Standard Deviations of all Subjects on the Vocabulary Test

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\overline{X}$	9.62	11.08	12.46	11.05
	SD	3.95	2.94	2.17	3.32
Moderate severity	$\overline{X}$	9.61	11.44	10.89	10.65
	SD	4.04	2.39	1.63	2.97
Low severity	$\overline{X}$	11.23	12.23	12.23	11.90
	SD	1.62	2.29	2.36	2.17
Column means & SD	$\overline{X}$	10.09	11.57	11.75	
	SD	3.55	2.58	2.15	

TABLE 6

Summary of Two-Way Analysis of Variance for the Scores on the Vocabulary Test

SOURCE	SF	SS	MS	F
Between Subjects	43	558.21		
Between Rows	2	35.74	17.87	1.402
Subjects Within Rows	41	522.47	12.74	
Within Subjects	88	567.33	36.43	
Between Columns	2	72.86	5.07	6.300**
Between Cells	4	20.28	5.78	0.876
Columns x Subjects Within Rows	82	474.19		
Total	131	1125.54		

** $p < .01$

Coding Test (from the WISC). This test measures the speed and accuracy of learning a new code. It involves skills related to spatial perception, immediate visual memory and motor control.

Based on the analysis of variance summaried in Table 8, it may be concluded that the index cases, siblings and matched controls have significantly different scores on the Coding Test, $p < .01$. No significant difference between the rows (see Table 7) nor an interaction effect was found.

TABLE 7

Mean Scores and Standard Deviations of all Subjects on the Coding Test

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\bar{X}$	9.85	13.46	12.62	11.97
	SD	3.63	2.13	2.56	3.24
Moderate severity	$\bar{X}$	10.17	11.94	11.78	11.30
	SD	3.44	2.48	3.05	3.12
Low severity	$\bar{X}$	11.54	12.38	10.85	11.59
	SD	2.50	2.17	1.99	3.32
Column means & SD	$\bar{\bar{X}}$	10.48	12.52	11.75	
	SD	3.33	2.38	2.71	

Auditory Memory (measured by the Digit Span Test of the WISC). The Digit Span Test involves attention, concentration, rote sequencial memory and memory reconstructuring (memory for the presented digits in reversed sequence).

TABLE 8

Summary of Two-Way Analysis of Variance for the Scores on the Coding Test

SOURCE	DF	SS	MS	F
Between Subjects	43	442.08		
Between Rows	2	10.41	5.21	0.495
Subjects Within Rows	41	431.67	10.53	
Within Subjects	88	712.00		
Between Columns	2	93.88	46.94	6.766**
Between Cells	4	49.23	12.31	1.774
Columns x Subjects Within Rows	82	568.89	6.94	
Total	131	1154.08		

** $p < .01$

Based on the summary of the analysis of variance presented in Table 10, it may be concluded that the index cases, siblings and matched controls differ in their auditory memory as measured by their scores on the Digit Span Test from the WISC ($p < .01$). There was no difference between the rows and no interaction effect ($p > .05$).

TABLE 9

Mean Scores and Standard Deviations of all Subjects on Auditory Memory

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\bar{X}$	7.54	10.23	10.62	9.46
	SD	3.25	0.89	2.44	2.76
Moderate severity	$\bar{X}$	7.61	10.61	11.50	9.91
	SD	2.79	2.19	2.71	3.07
Low severity	$\bar{X}$	9.62	11.15	10.00	10.59
	SD	1.69	1.92	2.42	2.15
Column means & SD	$\bar{X}$	8.18	10.66	11.09	
	SD	2.83	1.85	2.57	

The Auditory Memory Test includes two tasks: the first, "Digits Forward", requires sequential rote memory for digits repeated in the order of presentation; the other "Digits Backwards" requires the repetition of the digits in reverse to the order of presentation. The available norms on the WISC are for both tasks combined. Since these tasks presented different kinds of cognitive processing, a separate analysis was carried out for each. In order to use the WISC

TABLE 10

Summary of Two-Way Analysis of Variance for the Scores on Auditory Memory

SOURCE	DF	SS	MS	F
Between Subjects	43	342.93		
Between Rows	2	25.27	12.63	1.630
Subjects Within Rows	41	317.67	7.75	
Within Subjects	88	668.00		
Between Columns	2	216.86	108.43	20.834**
Between Cells	4	24.36	6.09	1.170
Columns x Subjects Within Rows	82	426.77	5.20	
Total	131	1010.93		

** $p < .01$

norms for each of these tasks separately, the scores of each subject on the "Digits Forwards" and "Digits Backwards" were calculated.

Based on Wechsler's basic assumption of internal consistency in the Digit Span Test, the row score on this test includes the unweighted raw scores on both the Auditory Memory Forward and Backward. Dr. James Heriot (2), proposed the following formula for calculating the scaled score for

Digits Forward and Digits Backward separately: If we let n represent the raw score on each of the above tasks than $2n-1$ would be the estimated raw score on the Digit Span Test if the whole test were to include only Digits Forward items, and $2n+1$ would be the estimated raw score on the Digit Span Test if the entire test were to include only Digits Backward items. The adjusted raw scores were converted into WISC scaled scores. The two-way analysis of variance carried out for both tasks separately yielded similar results. The index cases, siblings and matched comparisons differed in both Memory Forward and Memory Backward. In both cases these differences were significant at $p < .01$. Since findings for both Auditory Memory Forward and Auditory Memory Backward were consistent with the findings for the total score on Auditory Memory, the tables presenting the means of all subjects on these subtests and the summary tables of the analysis of variance for the above subtests were presented in the Appendix, Tables 62-65.

Raven Progressive Matrices (Raven, 1965). The Raven Progressive Matrices is a nonverbal measure of intellectual abilities, focussing on the abilities to analyze a visually perceptual field and understand the spatial relationships between its components. The subject is required to choose from six or eight suggested patterns the one that best completes a missing part in the test pattern.

The raw scores of each subject on this test are expressed in percentiles rather than scaled scores. In order to allow for the scores on this test to be analyzed by the same statistical method used for the other tests, the scores expressed in percentiles were transferred to T scores. T scores are frequently used in constructing norms for standardized psychological and educational tests. The values of the T scores were obtained directly from transferring the percentile of each subject to a normalized z score and then simply multiplying each z score by 10 and adding 50 to the product. The mean of a distribution of T scores is 50 and the standard deviation is equal to 10.

The following tables present the findings involving the T scores on the Raven Progressive Matrices.

On the basis of the analysis of variance summarized in Table 12, it may be concluded that the index cases, siblings and matched controls have significantly different scores on the Raven Progressive Matrices, (p <.01). No significant difference between the rows (see Table 11) nor an interaction effect were found (p >.05).

The Wide Range Achievement Test (WRAT). The Reading and Arithmetic tests on the WRAT were used as measures of the children's achievements in the two most central subjects taught in school, namely reading and arithmetic. Results will be presented separately for the Reading and the Arithmetic tests.

Reading Test. On this test the subject, depending on his age, is required to recognize and name the letters of the alphabet and read words of increasing difficulty.

TABLE 11

Mean Scores and Standard Deviations of All Subjects on the Raven Progressive Matrices

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\overline{X}$	51.73	58.54	60.62	56.96
	SD	16.75	6.33	6.71	11.68
Moderate severity	$\overline{X}$	54.03	61.66	60.34	58.68
	SD	10.47	4.79	5.77	8.15
Low severity	$\overline{X}$	61.60	60.04	61.08	60.91
	SD	5.98	4.63	5.03	5.28
Column means & SD	$\overline{X}$	55.59	60.26	60.64	
	SD	12.42	5.41	5.88	

In line with all the previously presented findings, the mean scores of the index cases on the Reading Test were lower than those of the siblings and matched controls. On the basis of the analysis of variance summarized in Table 14, it may be concluded that the index cases, siblings and matched comparisons had significantly different scores on the Reading Test,

TABLE 12

Summary of Two-Way Analysis of Variance for the T Scores on the Raven Progressive Matrices

SOURCE	DF	SS	MS	F
Between Subjects	43	3847.27		
Between Rows	2	305.38	152.69	1.768
Subjects Within Rows	41	3541.89	86.39	
Within Subjects	88	6447.78		
Between Columns	2	695.79	347.89	5.411**
Between Cells	4	479.76	119.94	1.865
Columns x Subjects Within Rows	82	5272.27	64.30	
Total	131	10295.05		

** $p < .01$

$p < .01$. No significant difference between the rows (see Table 13) nor an interaction effect were found ($p > .05$).

Arithmetic Test. The Arithmetic Test on the WRAT includes two parts; 1) the oral part which is aimed at the assessment of some basic abilities involved in the understanding of numbers, and 2) the written part which measures the ability to solve calculation exercises of varying degrees of complexity.

TABLE 13

Mean Scores and Standard Deviations of all Subjects on the Reading Test

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\bar{X}$	95.23	106.15	113.69	105.03
	SD	32.49	9.99	11.32	22.03
Moderate severity	$\bar{X}$	97.28	113.06	107.78	106.04
	SD	27.46	18.68	13.62	21.74
Low severity	$\bar{X}$	111.77	107.77	119.08	112.87
	SD	8.74	14.15	11.06	12.44
Column means & SD	$\bar{X}$	100.95	109.45	112.86	
	SD	26.32	15.52	13.12	

Examining the means presented in Table 15, it becomes apparent that the mean scores of the index cases are lower than those of their siblings and matched controls. Once again, as was the case in all the previously presented mean scores on other tests, the mean score of the low severity index cases is considerably higher than those of the high and

TABLE 14

Summary of Two-Way Analysis of Variance for the Scores on the Reading Test

SOURCE	DF	SS	MS	F
Between Subjects	43	19286.24	735.49	1.69
Between Rows	2	1470.98	434.52	
Subjects Within Rows	41	17815.26		
Within Subjects	88	32662.00		
Between Columns	2	3310.24	1655.12	4.981 **
Between Cells	4	2107.04	526.76	1.585
Columns x Subjects Within Rows	82	27244.7	332.25	
Total				

** $p < .01$

moderate severity groups. In this case the mean of the low severity index cases is higher than the means of both their siblings and their matched controls.

The summary of the analysis of variance presented in Table 16 leads to the conclusion that the index cases, siblings and matched controls differ significantly in their

TABLE 15

Mean Scores and Standard Deviations of all Subjects on the Arithmetic Test

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\overline{X}$	90.77	107.69	101.00	99.82
	SD	28.08	10.84	9.26	19.47
Moderate severity	$\overline{X}$	95.28	106.28	99.06	100.20
	SD	25.71	11.30	7.13	17.34
Low severity	$\overline{X}$	105.46	101.23	104.77	103.82
	SD	9.52	9.44	9.62	9.71
Column means & SD	$\overline{X}$	96.95	105.20	101.32	
	SD	23.75	10.97	8.89	

arithmetic ability measured by the Arithmetic Test ($p < .05$). No significant difference between the rows (see Table 15) nor an interaction effect were found ($p > .05$).

Summary of findings for Hypothesis A. The analyses of variance of all the above presented test scores revealed that significant differences exist between the index cases, siblings and

TABLE 16

Summary of Two-Way Analysis of Variance for the Scores on the Arithmetic Test

SOURCE	DF	SS	MS	F
Between Subjects	43	14172.33		0.588
Between Rows	2	395.41	197.70	
Subjects Within Rows	41	13776.91	336.02	
Within Subjects	88	20915.33		
Between Columns	2	1499.05	749.52	3.459*
Between Cells	4	1648.11	412.03	1.902
Columns x Subjects Within Rows	82	17768.18	216.69	
Total	131	35087.66		

* $p < .05$

matched controls. The next step in testing hypothesis A was to find which of the three subject groups differs from which other group. Table 17 presents the results of _t_ tests for dependent samples, comparing the three possible pairs of subject groups.

A significant difference was found between the index cases and their siblings as well as between the index cases and their matched controls on the following tests: PPVT, Vocabulary, Coding, Auditory Memory, Raven Progressive Matrices,

TABLE 17

Values of _t_ for Comparisons Between Index Cases, Siblings and Matched Controls

Comparison Between	df	PPVT	Vocabulary	Coding	Auditory Memory	Visual Memory	Raven	Reading	Arithmetic
Index cases and siblings	43	-1.949*	-2.894**	-3.358**	-4.965**	------	-2.438**	-1.920*	-2.316*
Index cases & matched controls	43	-2.252*	-3.066**	-2.184*	-5.730**	-1.473	-2.554**	-3.077**	-1.[illegible]
Siblings & matched controls	43	0.220	0.379	1.489	0.945	0.932	0.307	0.986	1.709

* $p < .05$ (one-tailed test)

** $p < .01$ (one-tailed test)

Note.- In the comparisons between the siblings and matched controls, for which the direction of difference was unpredictable, the two-tailed test was used.

and Reading. For the score on the Arithmetic Test, differences were found between the index cases and their siblings only. Comparing all test scores of the siblings to those of the matched comparisons did not yield any significant findings, i.e. these two groups do not differ in performance on any of the given tests.

Examination of the cell means in Tables 3,5,7,9,11,13, and 15 suggests that the large value of F for the differences between the groups of index cases, siblings and matched comparisons were effected mainly by the very low mean scores on the high and the moderate severity index cases. The mean scores of the low starvation index cases is in most cases very close numerically to the means of the siblings and matched comparisons. Based on this observation and on the lack of significant differences between the rows and interaction effect between rows and columns, separate *t* tests were carried out comparing the index cases in each level of severity of starvation with their siblings and their matched comparisons. Results of these tests are reported below for every one of the three degrees of starvation severity and for scores on each of the learning ability tests.

Table 18 presents the final results for Hypothesis A. According to this hypothesis, the scores of the index cases are lower than those of their siblings and the matched controls. In other words, in order to confirm this hypothesis with regard to scores on any one of the tests with the exception of the Visual Memory Test, the differences between the index cases

TABLE 18

Values of t for Comparisons Between Index Cases in Each Level of Starvation Severity, their Siblings and Matched Controls

	Comparison between	df	PPVT	Vocabulary	Coding	Auditory memory	Visual memory	Raven	Reading	Arithmetic
High severity	Index cases & siblings	12	1.235	1.334	-3.698**	-2.588*	---	1.352	1.128	-2.208*
	Index cases & matched c.	12	1.501	-2.778**	-3.639**	-2.826**	-1.957*	1.740	-2.011*	1.115
	Siblings & matched c.	12	0.195	-2.520*	0.935	0.533	---	0.711	-2.520*	1.3811
severity	Index cases & siblings	17	1.421	-2.076*	1.584	-3.360**	---	-3.489**	-2.256*	-1.888*
	Index cases & matched c.	17	-1.922*	1.366	1.485	-5.252**	-2.749**	-2.496*	1.682	0.699
	Siblings & matched c.	17	0.282	0.753	0.186	0.987	---	0.935	0.814	+2.326*
Low severity	Index cases & siblings	12	0.619	1.586	0.982	-2.992**	---	0.688	0.748	1.450
	Index cases & matched c.	12	0.283	1.274	0.821	-1.853*	0.844	0.237	-1.859*	0.214
	Siblings & matched c.	12	0.193	0.0	1.730	0.252	---	0.435	1.867	0.954

* $p < .05$ (one-tailed test)
** $p < .01$ (one-tailed test)

Note. - In the comparisons between the siblings and matched controls, for which the direction of difference was unpredictable, the two-tailed test was used.

and their siblings as well as the differences between the index cases and their matched controls have to be significant and in the expected direction. These conditions were met by the Auditory Memory Test in all three groups of starvation severity, by the Coding Test in the high severity group and by the Raven Progressive Matrices in the moderate severity group. Other significant differences between test scores were not consistent, i.e., they appeared in the comparison of the index cases to only one of the other two groups, or were coupled with a significant difference between the siblings and matched controls. These differences will be discussed further in Chapter IV.

Due to the fact that the Visual Memory Test scores could be compared only between subjects of the same age, only the comparisons between the index cases and their matched controls were carried out for this test. The values of t for the above comparisons were significant ($p < .05$) in both the high and moderate severity groups, suggesting that index cases in those groups have lower scores on visual memory, as predicted by Hypothesis A.

It should be stated here that the signs of all differences between means of the index cases and the other two groups were in the direction predicted by the hypothesis.

The results of the t test performed on the scores of Auditory Memory Forward and Auditory Memory Backward were consistent with the results for the total score on the

Auditory Memory Test, except for one case. In the comparison between the high severity index cases and their matched comparisons, the auditory memory forward did not yield a significant _t_, while the auditory memory backward, as well as the total score on auditory memory, pointed to a significant difference between the above two groups.

Testing of Hypothesis B

Hypothesis B deals with the social and emotional aspects of behavior represented by the scores on the factors of Immaturity, Overactivity, Conduct Problems and Personality Problems of the Ottawa School Behavior Checklist (OSBCL) (Pinn and McClure, 1969), and by the scores on the Vineland Social Maturity Scale (VSMS) (Doll, 1953). The OSBCL focuses on the child's behavior in school. The teacher (predominantly female) of each subject was asked to indicate whether she had observed the child behaving in certain ways listed on this checklist. The VSMS, filled out through the parental (mostly mothers) interviews, focuses on the child's ability to cope with activities of daily living. In addition to the OSBCL and the VSMS, Hypothesis B was tested on the Parental Estimate of Development Scale (PEDS) (Heriot, 1972). The PEDS required each parent to evaluate his or her child's mental development and predict his most likely future level of education and occupation.

Hypothesis B states: Index cases have higher factor scores on Immaturity, Overactivity, Conduct Problems, and

Personality Problems (derived from the OSBCL) and lower scores on the VSMS and the PEDS, as compared to their siblings and their matched controls.

The statistical method used in testing Hypothesis B was similar to that for testing Hypothesis A. The first step in the analysis was a two-way analysis of variance, carried out by the ANAVAR 2 computer program described previously. Since no significant differences between the subject groups were found, there was no need to proceed with t tests comparing all index cases to all subjects in the other groups. However, t tests for dependent samples were carried out to compare the index cases within each level of severity to their siblings and matched controls.

Tables 19-25 present the means and summary of the two-way analysis of variance between the index cases, siblings and matched controls on each of the above mentioned variables. The summary of the comparisons between the subject groups for each level of severity are presented in Table 26.

Ottawa School Behavior Checklist (OSBCL). The scores on this checklist were analyzed first for the total score and then for each factor measured. It should be noted that the total score includes more than the sum of the factor scores. Some behavior problems were not included in any of the factors measured but were included in the total score. The following tables present the mean scores of all subject groups on the OSBCL, followed by the results of the two-way analysis of variance performed on these scores.

TABLE 19

Means and Standard Deviations of all
Subjects on the Total Score of the OSBCL

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\overline{X}$	11.00	7.69	6.54	8.41
	SD	5.52	6.51	5.12	6.05
Moderate severity	$\overline{X}$	8.11	5.00	8.78	7.30
	SD	8.99	5.99	7.68	7.83
Low severity	$\overline{X}$	9.54	10.84	9.00	9.79
	SD	9.34	14.10	7.76	10.77
Column means & SD	$\overline{X}$	9.39	7.52	8.18	
	SD	8.33	9.58	7.13	

The two-way analysis of variance revealed no differences between the subject groups presented in the columns ($F=0.609$, $df=2,82$, $p>.05$). The rows ($F=1.79$, $df=2,41$, $p>.05$) and the cells ($F=0.89$, $df=4,82$, $p>.05$) in Table 19.

Immaturity Factor of the OBSCL

TABLE 20

Mean Scores and Standard Deviations of all Subjects on the Immaturity Factor of the OSBCL

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\overline{X}$	2.15	1.46	1.69	1.77
	SD	1.29	1.28	1.49	1.39
Moderate severity	$\overline{X}$	2.22	1.61	1.22	1.69
	SD	2.51	1.77	1.31	1.97
Low severity	$\overline{X}$	2.54	2.62	2.31	2.49
	SD	2.10	3.27	2.40	2.64
Column means & SD	$\overline{X}$	2.29	1.86	1.68	
	SD	2.10	2.27	1.81	

The two-way analysis of variance performed on the immaturity scores revealed no significant differences between the subject groups as presented in the columns. ($F=1.043$, $df=2,82$, $p > .05$), the rows ($F=1.675$, $df=2,41$, $p > .05$) and the cells ($F=0.257$, $df=4,82$, $p > .05$) of Table 20.

Overactivity Factor of the OSBCL

TABLE 21

Mean Scores and Standard Deviations of all Subjects on the Overactivity Factor of the OSBCL

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\bar{X}$	2.23	2.23	1.77	2.08
	SD	2.01	2.26	1.58	1.98
Moderate severity	$\bar{X}$	2.33	1.83	2.56	2.24
	SD	2.77	2.01	2.61	2.50
Low severity	$\bar{X}$	3.00	2.77	2.23	2.67
	SD	3.11	3.58	1.80	2.95
Column means & SD	$\bar{X}$	2.50	2.23	2.23	
	SD	2.70	2.66	2.14	

Based on the two-way analysis of variance carried out on the overactivity factor scores, it may be concluded that there was no significant difference between the index cases, siblings and matched controls ($F=0.1721$, $df=2,82$, $p > .05$).

the overactivity factor scores, it may be concluded that there was no significant difference between the index cases, siblings and matched controls (F=0.1721, df=2,82, p >.05). No significant difference between the rows in Table 21 (F=0.50, df=2,41, p >.05), nor an interaction effect (F=0.34, df=4,82, p >.05) was found.

Conduct Factor of the OSBCL

TABLE 22

Mean Scores and Standard Deviations of all Subjects on the Conduct Factor of the OSBCL

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\overline{X}$	2.77	1.85	1.85	2.15
	SD	1.72	1.99	1.83	1.90
Moderate severity	$\overline{X}$	2.00	1.72	1.67	1.80
	SD	2.45	1.99	1.91	2.14
Low severity	$\overline{X}$	2.54	2.15	2.23	2.31
	SD	2.76	2.63	2.45	2.62
Column means & SD	$\overline{X}$	2.39	1.89	1.89	
	SD	2.39	2.21	2.08	

The two-way analysis of variance performed on the Conduct scores shows no significant differences between the subject groups as presented in the columns (F=0.828, df=2,82, $p > .05$), the rows (F=0.469, df=2,41, $p > .05$) and the cells (F=0.128, df=4,82, $p > .05$) of the Table 22.

Personality Factor on the OSBCL

TABLE 23

Mean Scores and Standard Deviations of all Subjects on the Personality Factor of the OSBCL

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\bar{X}$	2.31	1.54	1.31	1.72
	SD	1.73	1.69	1.26	1.63
Moderate severity	$\bar{X}$	1.61	1.06	1.17	1.28
	SD	1.95	1.13	1.26	1.51
Low severity	$\bar{X}$	1.69	1.77	1.54	1.67
	SD	2.30	2.04	1.99	2.12
Column means &SD	$\bar{X}$	1.84	1.41	1.32	
	SD	2.02	1.64	1.52	

The two-way analysis of variance performed on the Personality scores shows no significant differences between the subject groups as presented in the columns (F=1.327, df=2,82, $p > .05$), the rows (F=0.635, df=2,41, $p > .05$) and the cells (F=0.361, df=4,82, $p > .05$) of Table 23.

In summary, no significant differences were found between or within the groups of the index cases, siblings, and matched controls with regard to their scores on the OSBCL. However, on the basis of the cell means in Tables 19-23, it should be noted that the high severity index cases had the highest scores on the total OSBCL as well as on the Conduct Factor and the Personality Factor of the OSBCL.

Vineland Social Maturity Scale (VSMS) (Doll, 1953).

TABLE 24

Mean Scores and Standard Deviations on VSMS for the Three Groups of Subjects Across Severity of Starvation of Index Cases

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\bar{X}$	134.38	148.77	152.31	145.15
	SD	20.20	26.28	18.88	23.35
Moderate severity	$\bar{X}$	145.33	156.33	135.39	145.69
	SD	33.33	39.03	17.94	32.53
Low severity	$\bar{X}$	144.85	144.77	137.62	142.41
	SD	34.09	28.68	24.35	29.51
Column means & SD	$\bar{X}$	141.95	150.68	141.05	
	SD	30.70	33.09	21.59	

The two-way analysis of variance performed on the VSMS scores shows no significant differences between the subject groups as presented in the columns ($F=1.828$, $df=2,82$, $p > .05$), the rows (F=0.108, df=2,41, p >.05), and the cells (F=1.560, df=4,82, p >.05) of Table 2 .

Parental Estimate of Development Scale (PEDS) (Heriot, 1972)

TABLE 25

Mean Scores and Standard Deviations on the PEDS
for the Three Groups of Subjects Across
Severity of Starvation of Index Cases

Severity of starvation		Index cases	Siblings	Matched controls	Row means & SD
High severity	$\overline{X}$	108.00	115.15	115.77	112.97
	SD	21.45	6.10	9.42	14.42
Moderate severity	$\overline{X}$	105.94	114.72	114.72	111.80
	SD	18.80	7.40	8.00	13.21
Low severity	$\overline{X}$	120.33	115.23	118.31	117.92
	SD	7.43	6.31	11.55	8.97
Column means & SD	$\overline{X}$	110.77	115.00	116.09	
	SD	18.31	6.73	6.70	

The two-way analysis of variance carried out for the scores on the PEDS lead to the conclusion that there was no significant difference between the index cases, siblings, and matched comparison groups (F=2.912, df=2,82, p > .05). It should be noted here that the numerical value of F in this case is close to the critical value (F=3.11) for the .05 level of significance, suggesting a trend towards a difference between the index cases and both the siblings and the matched controls. No significant difference was found between the rows (F=1.987, df=2,41, $p > .05$), and between the cells (F=1.846, df=4,82, $p > .05$) of Table 25.

The fact that the column of the index cases contained both the lowest and the highest cell means reduced the difference between the column mean of the index cases and that of the other groups, leading to a smaller F value and consequently to the conclusion of no difference between the groups.

Summary of findings for Hypothesis B. Hypothesis B dealt with differences between the index cases, siblings and matched controls in social and emotional adjustment and development as measured by the OSBCL, VSMS, and PEDS. The analysis of data testing this hypothesis lead to the conclusion that the three subject groups did not differ significantly on any of the above measures. Though no significant differences were found between the cells, the high severity index cases were consistently found (except for Immaturity and Overactivity on the OSBCL and for the PEDS) to have the highest or lowest scores, whichever one indicated more behavior problems. The low severity index cases, with the exception of the Immaturity scores, had consistently "better" scores than the high severity index cases.

Separate comparisons, using *t* test for dependent samples, were carried out between the index cases in each starvation level, their siblings and their matched controls. These comparisons are presented in Table 26.

TABLE 26

Values of t Comparing Index Cases of Each Starvation Level, their Siblings, and Matched Controls on Measures of Social and Emotional Adjustment

Starvation severity	Comparison between:	PEDS	VSMS	OSBCL	Immaturity	Overactivity	Conduct	Personality
High severity (df=12)	Index cases and siblings	1.012	-2.625*	1.627	1.354	0.0	1.332	1.690
	Index cases and matched c.	1.399	-2.033*	1.729	0.665	0.703	1.316	1.331
	Siblings and matched c.	0.169	0.379	0.426	0.371	0.496	0.0	0.344
Moderate severity (df=17)	Index cases and siblings	-2.096*	1.290	1.229	0.788	0.586	0.359	1.426
	Index cases and matched c.	-2.675**	1.071	0.203	1.256	0.212	0.375	0.827
	Siblings and matched c.	0.0	+2.354*	1.823	0.654	0.908	0.091	0.345
Low severity (df=12)	Index cases and siblings	+2.678*	0.010	0.359	0.092	0.217	0.493	0.106
	Index cases and matched c.	0.581	0.544	0.170	0.274	0.823	0.493	0.176
	Siblings and matched c.	0.778	0.546	0.435	0.283	0.494	0.111	0.330

** $p < .01$ (for one-tailed t test)
* $p < .05$ (for one-tailed t test)

Note. - For the comparisons between the siblings and matched controls, for which the direction of difference was unpredictable, the two-tailed test was used.

Based on Table 26, the index cases in the high severity group were found to have lower VSMS scores than their siblings and the matched controls ($p < .05$). This finding indicated that they showed less maturity in everyday activities as evaluated by the VSMS. In the moderate severity group there was no difference between the index cases, their siblings and matched controls on the VSMS but there was a significant difference between the index cases and their siblings ($p < .05$) and between the index cases and their matched controls ($p < .01$) on the PEDS. The index cases had lower scores on the PEDS, measuring their parents' evaluation of their intellectual development. It should be noted here that the siblings in the moderate severity group had higher VSMS scores than the matched controls.

In the low severity group the index cases were found to have higher PEDS scores than their siblings ($p < .05$).

Intragroup Comparisons

The intragroup analysis includes hypotheses involving comparisons within the group of index cases. These comparisons focus on differences between index cases who suffered from varying degrees of starvation at different periods in infancy.

Testing of Hypothesis C

Hypothesis C states that the severity of starvation experienced by the index cases is negatively related to their standard test scores.

The Pearson Product Moment Correlation Coefficient between the test scores and degree of starvation of the index cases, was calculated. This correlation coefficient is presented in Table 27 for each of the tests.

TABLE 27

The Correlation Coefficient Between Tests of Learning Abilities and Degree of Starvation

Name of test	Correlation coefficient	Level of significance
PPVT	-0.323	$p < .05$
Vocabulary	-0.253	$p < .05$
Coding	-0.315	$p < .05$
Auditory memory	-0.431	$p < .01$
(Memory Forwards)	-0.332	$p < .05$
(Menory Backwards)	-0.339	$p < .01$
Visual Memory	-0.258	$p < .05$
Raven Progressive Matrices	-0.383	$p < .01$
Reading	-0.362	$p < .01$
Arithmetic	-0.359	$p < .01$

Note. - Critical values of r for df=49 are 0.276 and 0.358 respectively for the .05 and .01 levels of significance.

Summary of findings for Hypothesis C. A significant correlation was found between all tests of learning abilities and the severity of starvation expressed in percentages of weight loss due to PS in infancy. All the correlations presented in Table 27 are negative, indicating that a negative relationship exists between the learning abilities measured and the severity of starvation. In other words, lower test scores are related to higher degrees of starvation severity. The learning abilities that were most significantly correlated with severity of starvation ($p < .01$) were: auditory memory tested by the WISC Digit Span Test, understanding spatial relations measured by the Raven Progressive Matrices, and the achievement tests in reading and arithmetic as measured by the Reading and Arithmetic Tests on the WRAT.

Testing of Hypotheses D and E

Hypotheses D and E are as follows:

Hypothesis D: There are differences in standard test scores between subjects who suffered from starvation at different periods of time in infancy.

Hypothesis E: For each learning ability assessed, there is an interaction effect between the time of onset and the severity of starvation, resulting in lower scores with greater severity of starvation for certain periods of starvation onset.

To test hypotheses D and E, a two-way analysis of variance for cells with unequal N's (Winer, 1962) was carried out using the AVARUN Computer program written in Fortran IV. (Unlike the two-way analysis of variance carried out to test hypotheses A and B, this analysis did not involve dependent samples since the index cases are not matched within themselves). The table of the above analysis of variance included 3 columns and 3 rows. The columns presented the three severity of starvation levels discussed earlier in this chapter, i.e., 1) high severity subjects who suffered a weight deficit of 21% and over; 2) moderate severity subjects who suffered a weight deficit of 11-20%, and 3) low severity subjects who suffered a weight deficit of less than 10% or no deficit at all. The three rows divided the index cases according to their age (in days) at the onset of starvation. The rows included index cases whose onset of starvation was within the following ranges: 1) between 1 and 20 days; 2) between 21 and 30 days, and 3) 31 and 60 days.

The only index case for whom starvation onset was at 102 days of age, was excluded from this analysis, since the next highest age of starvation onset was 60 days. The lowest age of starvation onset was 3 days. Results will now be presented for each test of learning ability separately.

Both differences between rows and between columns in the analysis of variance presented in Table 29, did not meet the .05 level of significance, i.e., no significant differences were found between subjects who had PS of varying degrees of severity and at different periods in infancy. The value of F for the difference between the columns is smaller than that for the rows.

PPVT

TABLE 28

Mean Scores and Standard Deviations of all Index Cases on the PPVT

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\overline{X}$	108.00	101.89	113.80	106.47
	SD	15.52	22.13	14.29	18.84
21-30	$\overline{X}$	110.50	110.33	119.75	112.75
	SD	14.21	10.48	7.50	11.52
31-60	$\overline{X}$	82.50	102.50	106.75	99.62
	SD	58.25	23.85	9.32	30.67
Column means & SD	$\overline{X}$	101.31	104.68	111.88	
	SD	33.82	18.94	11.37	

TABLE 29

Summary of Two-Way Analysis of Variance for the PPVT Scores

Source	SS	DF	MS	F
Between Rows	1991.72	2	995.86	2.049
Between Columns	1288.34	2	644.17	1.325
Between Cells	967.59	4	241.90	0.498
Within Cells	19438.77	40	485.97	

Vocabulary

TABLE 30

Mean Scores and Standard Deviations of Index
Cases on the Vocabulary Test

Age of starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\bar{X}$	8.33	8.89	10.80	9.35
	SD	3.05	4.29	1.64	3.46
21-30	$\bar{X}$	11.17	9.17	11.50	10.50
	SD	3.31	4.62	1.29	3.50
31-60	$\bar{X}$	8.50	10.75	10.88	10.25
	SD	5.97	4.11	2.17	3.72
Column means & SD	$\bar{X}$	9.69	9.37	11.00	
	SD	4.13	4.18	1.77	

TABLE 31

Summary of Two-Way Analysis of Variance for the
Vocabulary Test Scores

Source	SS	DF	MS	F
Between Rows	11.80	2	5.90	0.442
Between Columns	25.11	2	12.55	0.941
Between Cells	23.98	4	5.99	0.449
Within Cells	533.65	40	13.34	

The vocabulary scores were not found to be affected by the level of starvation severity or by the time of starvation onset. The difference between the means of the rows, as well as the difference between the means of the columns in Table 30, were not significant ($p > .05$). No significant difference between cells was found ($p > .05$).

Coding

TABLE 32

Mean Scores and Standard Deviations of Index Cases on the Coding Test

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\overline{X}$	9.33	9.56	12.40	10.35
	SD	1.53	4.45	2.07	3.62
21-30	$\overline{X}$	10.83	9.67	12.50	10.81
	SD	2.40	3.93	3.11	3.21
31-60	$\overline{X}$	8.50	10.75	11.13	10.38
	SD	6.35	1.71	2.23	3.50
Column means & SD	$\overline{X}$	9.77	9.84	11.82	
	SD	3.75	3.72	2.35	

Though none of the differences evaluated in Table 33 reached the .05 level of significance, it should be noted that there was a trend toward differences between the three severity levels.

TABLE 33

Summary of Two-Way Analysis of Variance
for the Coding Test Scores

Source	SS	DF	MS	F
Between Rows	5.75	2	2.88	0.239
Between Columns	49.92	2	24.96	2.080
Between Cells	17.77	4	4.44	0.370
Within Cells	479.88	40	11.99	

Auditory Memory

TABLE 34

Mean Scores and Standard Deviations of Index
Cases on the Auditory Memory Test

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\overline{X}$	7.67	6.67	9.20	7.59
	SD	1.53	3.50	1.92	2.94
21-30	$\overline{X}$	8.00	7.33	10.25	8.31
	SD	2.19	1.86	0.96	2.09
31-60	$\overline{X}$	5.50	9.50	9.63	8.56
	SD	3.20	1.73	1.92	3.33
Column means & SD	$\overline{X}$	7.15	7.47	9.65	
	SD	3.24	2.86	1.69	

TABLE 35

Summary of Two-Way Analysis of Variance for the Auditory Memory Test Scores

Source	SS	DF	MS	F
Between Rows	3.41	2	1.70	0.246
Between Columns	53.47	2	26.73	3.855*
Between Cells	38.52	2	9.63	1.389
Within Cells	227.42	40	6.94	

* $p < .05$

The differences between the scores of subjects in the columns of Table 34 was found to be significant ($p < .05$) i.e. the degree of starvation severity had an effect on the Auditory Memory Test scores. Differences in time of starvation onset did not affect the subject's scores. None of the cells was significantly different from the others. The high severity subjects for whom onset of starvation was between 31 and 60 days, had the lowest mean scores of all cell means.

In addition to the above analysis, separate analyses were carried out for the scores on Auditory Memory Forwards (AMF) and for Auditory Memory Backwards (AMB). (These analyses are presented in the Appendix). In both cases, findings were in line with the findings presented above for the total score on auditory memory, with one exception:

The value of F for the differences between columns of AMF, did not meet the .05 level of significance ($F=2.81$, $df=2,41$, $p > .05$).

Visual Memory

TABLE 36

Mean Scores and Standard Deviations of Index Cases on the Visual Memory Test

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\bar{X}$	130.67	97.78	104.00	105.41
	SD	13.58	30.97	44.16	33.81
21-30	$\bar{X}$	114.67	105.00	124.75	113.56
	SD	25.61	29.42	16.78	25.03
31-60	$\bar{X}$	75.75	111.25	123.88	108.68
	SD	51.14	15.13	30.79	37.75
Column means & SD	$\bar{X}$	106.38	102.89	118.23	
	SD	38.11	27.11	32.33	

TABLE 37

Summary of Two-Way Analysis of Variance for the Visual Memory Test Scores

Source	SS	DF	MS	F
Between Rows	935.69	2	467.84	0.474
Between Columns	1367.89	2	683.95	0.693
Between Cells	8593.92	4	2148.48	2.178
Within Cells	39466.68	40	986.67	

The differences between the rows, columns or cells were not found to be significant.

Raven Progressive Matrices

TABLE 38

Mean Scores and Standard Deviations of Index Cases on the Raven Progressive Matrices

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\overline{X}$	54.27	52.98	58.56	54.85
	SD	18.08	11.02	11.13	11.79
21-30	$\overline{X}$	58.23	52.23	59.93	56.41
	SD	5.73	13.65	8.07	9.88
31-60	$\overline{X}$	42.53	53.98	61.83	55.03
	SD	28.35	12.42	5.79	16.55
Column means & SD	$\overline{X}$	52.49	52.95	60.42	
	SD	17.87	11.48	7.74	

TABLE 39

Summary of Two-Way Analysis of Variance for the Scores on the Raven Progressive Matrices

Source	SS	DF	MS	F
Between Rows	120.14	2	60.07	0.368
Between Columns	595.25	2	297.62	1.826
Between Cells	561.65	4	140.41	0.861
Within Cells	6520.72	40	163.02	

The differences between the rows, between the columns, and between the cells in Table 38 were found to be insignificant ($p > .05$). The high severity subjects whose onset of starvation was between 31 and 60 days of age, had the lowest of all cell mean scores on the Raven Progressive Matrices.

Reading

TABLE 40

Mean Scores and Standard Deviations of Index Cases on the Reading Test

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\overline{X}$	100.33	89.33	108.40	96.88
	SD	12.10	38.34	10.16	29.24
21-30	$\overline{X}$	106.17	107.00	109.00	107.19
	SD	23.58	11.12	10.95	15.87
31-60	$\overline{X}$	73.00	99.75	109.13	97.75
	SD	50.98	3.86	13.13	28.93
Column means & SD	$\overline{X}$	94.62	97.10	108.88	
	SD	33.71	27.47	11.13	

The differences between the rows, between the columns and between the cells of Table 40 were found to be insignificant ($p > .05$).

TABLE 41

Summary of Two-Way Analysis of Variance for the Reading Test Scores

Source	SS	DF	MS	F
Between Rows	1331.19	2	665.59	1.054
Between Columns	1842.13	2	921.06	1.458
Between Cells	2482.41	2	620.60	0.982
Within Cells	25272.33	40	631.81	

Arithmetic

TABLE 42

Mean Scores and Standard Deviations of Index Cases on the Arithmetic Test

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\bar{X}$	96.67	87.22	101.00	92.94
	SD	17.01	35.48	4.85	26.70
21-30	$\bar{X}$	102.33	98.17	101.00	100.44
	SD	8.12	19.41	8.98	12.93
31-60	$\bar{X}$	67.00	101.25	107.38	95.75
	SD	44.83	6.99	11.16	27.76
Column means & SD	$\bar{X}$	90.15	93.63	104.00	
	SD	29.01	26.69	9.29	

TABLE 43

Summary of Two-Way Analysis of Variance for the Arithmetic Test

Source	SS	DF	MS	F
Between Rows	556.60	2	278.30	0.550
Between Columns	1524.35	2	762.17	1.506
Between Cells	3601.50	4	900.37	1.779
Within Cells	20245.01	40	506.13	

The differences between the rows, between columns and between cells of Table 43 were found to be insignificant ($p > .05$).

Summary of findings for Hypotheses D and E. The two above hypotheses were not confirmed by the statistical analyses. No significant differences were found between the test scores of index cases in the 1-20, 21-30, and 31-60 days of age at onset of starvation. None of the cells in the above analyses of variance were found to differ significantly from the others. Thus, it may be concluded that no interaction effect was detected in this study between severity of starvation and time of its onset.

Testing of Hypotheses F, G, and H

Hypotheses A, C, D and E dealt with the subjects' scores on various learning ability tests. Hypotheses F, G, and H deal with the subjects' social and emotional adjustment as evaluated by their parents and teachers.

Hypotheses F, G, and H are as follows:

Hypothesis F: There are differences in the scores of Immaturity, Overactivity, Conduct problems and Personality problems, between subjects who suffered from starvation at different periods in infancy.

Hypothesis G: Subjects who suffered from severe starvation have higher factor scores on the Ottawa School Behavior Checklist (OSBCL) and lower scores on the Vineland Social Maturity Scale (VSMS), and Parental Estimate of Development (PEDS) as compared to subjects who suffered from "milder" starvation.

Hypothesis H: For each of the factors of behavior problems assessed, there is an interaction between the time of onset and the severity of starvation, resulting in higher scores with greater severity of starvation for certain periods of starvation onset.

A two-way analysis of variance for unequal N's as previously described, was carried out for Hypotheses F, G, and H.

Findings concerning Hypotheses F, G, and H are presented in Tables 44-57 for each of the behavioral measures used in this study.

The differences between the rows, between the columns, and between the cells of Table 44 were found to be insignificant ($p > .05$). The severity level of starvation as well as the time of its onset were not found to have a statistically significant effect on the subjects' behavior as estimated by their parents on the Parental Estimate.

Parental Estimate

TABLE 44

Mean Scores and Standard Deviations of Index Cases on the Parental Estimate of Development Scale

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\bar{X}$	114.67	99.67	117.40	107.53
	SD	11.59	25.51	4.56	20.54
21-30	$\bar{X}$	114.83	110.16	115.25	113.19
	SD	5.95	7.41	10.72	7.68
31-60	$\bar{X}$	93.75	114.00	121.00	112.44
	SD	37.70	7.44	7.43	21.31
Column means & SD	$\bar{X}$	108.31	106.00	118.59	
	SD	22.24	18.81	7.55	

TABLE 45

Summary of Two-Way Analysis of Variance for the Parental Estimate Scores

Source	SS	DF	MS	F
Between Rows	115.33	2	57.67	0.207
Between Columns	978.82	2	489.41	1.753
Between Cells	1929.83	4	482.46	1.728
Within Cells	11169.03	40	279.23	

Vineland Social Maturity Scale (VSMS)

TABLE 46

Mean Scores and Standard Deviations of Index Cases on the VSMS

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\bar{X}$	123.33	142.44	121.40	132.88
	SD	12.52	34.21	18.85	28.01
21-30	$\bar{X}$	150.17	150.67	126.25	144.38
	SD	18.83	32.39	11.84	24.75
31-60	$\bar{X}$	117.00	144.25	161.63	146.13
	SD	14.17	41.39	40.42	38.73
Column means & SD	$\bar{X}$	133.77	145.42	141.47	
	SD	21.32	33.33	34.88	

TABLE 47

Summary of Two-Way Analysis of Variance for the VSMS Scores

Source	SS	DF	MS	F
Between Rows	1556.83	2	778.41	0.879
Between Columns	1801.24	2	900.62	1.017
Between Cells	6320.81	4	1580.20	1.785
Within Cells	35409.63	40	885.24	

The differences between the rows, between the columns, and between the cells of Table 46 were found to be insignificant ($p > .05$). The severity level of starvation as well as the time of its onset were not found to have a statistically significant effect on the subjects' behavior as estimated by their parents on the VSMS.

Ottawa School Behavior Checklist (OSBCL)

TABLE 48

Mean Scores and Standard Deviations of Index Cases on the OSBCL

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\bar{X}$	11.33	5.67	3.40	6.00
	SD	4.16	7.00	2.20	6.21
21-30	$\bar{X}$	9.83	14.00	17.50	13.31
	SD	4.88	12.08	9.94	8.88
31-60	$\bar{X}$	10.00	5.25	7.13	7.38
	SD	7.07	3.86	8.49	7.05
Column means & SD	$\bar{X}$	10.23	8.21	8.47	
	SD		9.01	8.78	

The difference between the rows of Table 52 was found to be significant ($p < .05$). The difference between the columns or between the cells did not reach the .05 level of significance.

TABLE 49

Summary of Two-Way Analysis of Variance
for Scores on the OSBCL

Source	SS	DF	MS	F
Between Rows	432.61	2	216.30	3.871*
Between Columns	31.63	2	15.81	0.283
Between Cells	329.32	4	82.33	1.473
Within Cells	2235.33	40	55.88	

* $p < .05$

Immaturity Factor (on the OSBCL)

TABLE 50

Mean Scores and Standard Deviations of Index
Cases on the Immaturity Factor

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\bar{X}$	2.33	1.33	0.80	1.35
	SD	1.53	1.32	1.30	1.37
21-30	$\bar{X}$	2.33	3.83	4.50	3.44
	SD	0.82	3.76	1.29	2.48
31-60	$\bar{X}$	1.75	1.75	1.88	1.81
	SD	2.06	1.26	1.96	1.72
Column means & SD	$\bar{X}$	2.15	2.21	2.18	
	SD	1.35	2.51	2.10	

TABLE 51

Summary of Two-Way Analysis of Variance for Scores on the Immaturity Factor

Source	SS	DF	MS	F
Between Rows	36.31	2	18.15	4.873*
Between Columns	0.48	2	0.24	0.065
Between Cells	17.42	4	4.36	1.169
Within Cells	149.01	40	3.73	

* $p < .05$

The difference between the rows in Table 50 was found to be significant ($p < .05$), i.e. the time of starvation onset affected the subjects' level of maturity as measured by the Immaturity factor on the OSBCL. The subjects whose onset of starvation was between 21 and 30 days of age had the highest immaturity scores, i.e. they were most immature. No significant difference was found between the columns or between the rows.

Overactivity Factor (on the OSBCL). The difference between the rows in Table 52 was found to be significant ($p < .01$). This finding indicates that the time of starvation onset affected the subject's activity level as evaluated by their teachers on the Overactivity factor, OSBCL. The subjects whose starvation onset was between 21 and 30 days of age were found to have the highest overactivity scores. The level of starvation severity was not found to have an effect on overactivity scores. No significant difference was found between the cells in Table 52.

TABLE 52

Mean Scores and Standard Deviations of Index Cases on the Overactivity Factor

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\overline{X}$	2.00	1.56	0.60	1.35
	SD	1.00	2.60	1.34	2.06
21-30	$\overline{X}$	2.67	3.83	6.00	3.94
	SD	2.50	3.43	2.16	2.96
31-60	$\overline{X}$	2.00	1.75	1.88	1.88
	SD	2.31	1.26	2.85	2.28
Column means & SD	$\overline{X}$	2.31	2.32	2.47	
	SD	2.06	2.77	3.04	

TABLE 53

Summary of Two-Way Analysis of Variance for the Scores on Overactivity

Source	SS	DF	MS	F
Between Rows	64.26	2	32.13	5.241**
Between Columns	2.85	2	1.42	0.232
Between Cells	30.07	4	7.52	1.225
Within Cells	245.21	40	6.13	

** $p < .01$

Conduct Factor (on the O BCL)

TABLE 54

Mean Scores and Standard Deviations of Index Cases on the Conduct Factor

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\overline{X}$	2.00	1.33	0.80	1.29
	SD	0.0	1.94	1.79	1.69
21-30	$\overline{X}$	3.17	3.33	5.25	3.75
	SD	2.23	3.45	2.99	2.86
31.60	$\overline{X}$	2.25	1.50	1.50	1.69
	SD	1.71	1.00	2.00	1.66
Column means & SD	$\overline{X}$	2.62	2.00	2.18	
	SD	1.76	2.45	2.72	

TABLE 55

Summary of Two-Way Analysis of Variance for the Scores on the Conduct Factor

Source	SS	DF	MS	F
Between Rows	54.79	2	27.39	5.664**
Between Columns	1.89	2	0.94	0.195
Between Cells	16.47	4	4.12	0.851
Within Cells	193.47	40	4.84	

** $p < .01$

The difference between the rows in Table 54 was found to be significant ($p < .01$). The subjects in the 21-30 days of age at starvation onset had the highest conduct factor score, i.e., more conduct problems than the other groups of starvation onset. Differences between the columns and between the cells were found to be insignificant ($p > .05$).

Personality Factor (on the OSBCL)

TABLE 56

Mean Scores and Standard Deviations of Index Cases on the Personality Factor

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\bar{X}$	2.67	1.11	1.20	1.41
	SD	1.56	1.76	1.17	1.81
21-30	$\bar{X}$	1.83	2.67	3.75	2.63
	SD	1.47	2.50	3.10	2.31
31-60	$\bar{X}$	1.75	1.25	1.00	1.25
	SD	1.71	0.96	1.41	1.34
Column means & SD	$\bar{X}$	2.00	1.63	1.71	
	SD	1.41	1.95	2.29	

The differences between the rows, between the columns as well as between the cells, were found to be insignificant ($p > .05$). Based on these findings, it may be concluded that the Personality Factor was not differentially affected by the severity of starvation or its period of onset.

TABLE 57

Summary of Two-Way Analysis of Variance
for the Scores on the Personality Factor

Source	SS	DF	MS	F
Between Rows	16.04	2	8.02	2.248
Between Columns	1.31	2	0.66	0.184
Between Cells	16.49	4	4.12	1.155
Within Cells	142.77	40	3.57	

Summary of findings for Hypotheses F, G and H. On the basis of the analyses presented in Tables 48-55, it may be concluded that the time of starvation onset affected the subjects' scores on the Immaturity, Overactivity, and Conduct Factors on the OSBCL as well as the total score on that test. The subjects with most problems in the above factors were those for whom starvation started between 21 and 30 days of age. The level of starvation severity did not affect the subjects' scores on the behavioral measures tested under the above hypotheses. No interaction effect was found between time of onset and severity of starvation. Though no significant differences were found between the cells in all the analysis of variance presented under these hypotheses, the scores of the low severity index cases for whom starvation onset was between 21 and 30 days of age had consistently higher scores, i.e., more behavior problems than the subjects in all other cells.

Table 58 presents a summary of t values for all possible comparisons between the groups of starvation onset. These t tests were carried out in order to determine whether the group of 21-30 days of age at starvation onset had more behavior problems than the 1-20 group as well as the 21-30 group or only as compared to one of these groups and not to the other. Data presented in Table 58 leads to the conclusion that the 21-30 group had more problems related to immaturity, overactivity, and conduct as compared to both other groups.

TABLE 58

Values of t for the Comparisons Between the OSBCL Scores of the Three Groups of Starvation Onset

Comparison between	df	Immaturity	Overactivity	Conduct Factor	Personality Factor	OSBCL
1-20 & 21-30	31	-3.019**	-2.930**	-2.024**	1.689	-2.754**
1-20 & 31-60	31	0.852	0.691	0.674	0.291	0.595
21-30 & 31-60	30	+2.156*	+2.212*	+2.491**	+2.491**	+2.094*

* $p < .05$ (one-tailed test)
** $p < .01$ (one-tailed test)

It may be noted that in many of the preceding tables, there is some heterogeneity of variance, which could increase the possibility of committing a Type I error, i.e. rejecting a true null hypothesis. However, Bartlett's test for homogeneity of variance did not point to significant differences between the group variances of the index cases, siblings and matched controls on all tests, with the exceptions of the PPVT (Table 3), Raven (Table 11), Reading (Table 13), and Arithmetic (Table 15). Significant differences between the variances of the above groups were also found on the following measures of general adjustment: Total score on the OSBCL (Table 19), VSMS (Table 24), and PEDS (Table 25). For the comparison between the groups of starvation onset, variances were found to differ significantly on the PPVT (Table 28). For all the tests specified above, the null hypothesis of equality between the compared groups was not rejected, thus, no Type I error was committed.

Moreover, the heterogeneity in variances between the index cases, siblings and matched controls occurred because the group of index cases included subjects who were severely retarded as well as others who were intellectually normal (as defined by test norms). Excluding the extreme cases from this group would have lowered the variance but it would have also distorted the answers to the questions asked in the present study.

Aside of homogeneity of variance, the other two conditions considered with regard to making a Type I error are: 1) Normality of the distribution of values for the analyzed variables and 2) Equality of the number of subjects in the compared groups. It should be stressed here that all comparisons between the matched groups, involved groups with equal numbers of subjects and the values of the variables analyzed (standard test scores) theoretically have a normal distribution. In conditions for which "normality" and equality of N are satisfied, the violation of homogeneity of variance was not found to have a significant effect on the probability of making a Type I error (Glass et al., 1972). Thus, conclusions based on differences in mean scores between the matched groups are valid regardless of homogeneity of variances.

Effects of Starvation in Infancy on Subsequent Physical Growth

The subjects' physical growth was assessed by three measures: head circumference (HC), height, and weight. For each subject these three measures were taken immediately following his learning abilities tests. Information about the height of the parents was gathered through the parental interviews. In order to enable comparisons between subjects of different ages as well as between subjects and their parents, the measures of height, weight, and head circumference were converted into percentiles, based on population norms for each age and sex. Height and weight percentiles for the children who were under 6 years and 6 months old at the time of the examination were determined from data presented by Meredith (Nelson, 1969). Percentiles for the older children and their parents were calculated from height and weight distributions published by the National Center for Health

Statistics, (U.S. Dept. of H.E.W., 1966). The percentiles were then divided into 7 categories of range which were ranked as follows: 1) 2-10, 2) 10-25, 3) 25-50, 4) 50-75, 5) 75-90, 6) 90-95, and 7) 95 and over.

Comparisons were carried out between the frequency distributions of the index cases, siblings and matched controls in each of the categories of percentile ranges discussed above. Because of very low frequencies at both ends of the percentile rank, the frequencies for categories 1 and 2, 6 and 7 were combined. Category 1 includes subjects whose height, weight or HC lie between percentile 2 and 25, category 5 includes the percentiles of 90 and over. Tables 59-61 present the frequency distribution of HC, height and weight of index cases, siblings, and matched controls. These tables are followed by the results of Chi Square Test carried out for each of the above frequency distributions.

Tables 59, 60, and 61 present the distributions of the head circumference, height and weight of all the subjects. χ^2 tests were carried out for the hypothesis that any of the cells in the above tables differ significantly from the expected frequency under the assumption that these samples were taken from the same population with regard to the variable measured. Since none of the above χ^2 values was found to be significant at the .05 level, it may be concluded that the distribution of HC, height and weight in the groups of index cases, siblings and matched controls do not differ significantly. (The differences between the distributions of height of the subjects' mothers as well as fathers were

TABLE 59

Head Circumference Frequency Distribution of Index Cases, Siblings and Matched Controls

	Categories of percentile ranges					
	1 (2-25%)	2 (25-50%)	3 (50-75%)	4 (75-90%)	5 (90-100%)	No. of subject
Index cases	8	22	13	4	3	50
Siblings	8	12	8	9	7	44
Matched controls	6	16	17	6	5	50
No. of subjects	22	50	38	19	15	144

Results of the χ^2 test for the above frequency distributions was χ^2=10.422, df=8, p .20.

TABLE 60

Height Frequency Distribution of Index Cases, Siblings and Matched Controls

	Categories of percentile ranges					
	1 (2-25%)	2 (25-50%)	3 (50-75%)	4 (75-90%)	5 (90-100%)	No. of subjec
Index cases	7	6	18	11	8	20
Siblings	8	6	9	13	8	44
Matched controls	6	12	8	12	12	50
No. of subjects	21	24	35	36	28	

Results of the χ^2 test for the above frequency distributions was χ^2=9.087, df=8, p .30.

TABLE 61

Weight Frequency Distribution of Index Cases, Siblings and Matched Controls

	Categories of percentile ranges					
	1 (2-25%)	2 (25-50%	3 (50-75%)	4 (75-90%)	5 (90-100%)	No. of subjects
Index cases	7	7	13	13	10	50
Siblings	8	4	14	11	7	44
Matched controls	2	9	17	14	8	50
No. of subjects	17	20	44	38	25	144

Results of the χ^2 test for the above frequency distributions was: $\chi^2=6.604$, df=8, p .50.

also found to be within the expected range).

In summary, a brief period of starvation in early infancy does not have a significant effect on physical growth of the body as measured by the head circumference, height and weight.

Chapter IV

DISCUSSION

Background of the Study

Both animal and human studies suggest the existence of critical periods in brain growth, during which any interference with brain growth causes an irreversible reduction in cell number and thus, a long term deficit in intellectual functioning (Winick, et al., 1966, 1967, 1968; Dobbing, 1970). Reported studies from different countries have shown that children who have suffered from protein malnutrition early in life subsequently score more poorly on a variety of mental tests when compared to control children (Birch, et al., 1972; Chase and Martin, 1970; Cravioto and Robles, 1965 ; Latham, et al., 1969, Pollitt and Granoff, 1967).

The isolated effects of malnutrition on intellectual functioning are difficult to establish in these studies of human subjects because of the overwhelming number of confounding social and cultural variables. Thus, if a child was shown to have a poor vocabulary it is rather difficult to demonstrate a single primary cause. In most studies dates were recorded on the child's condition when he first received medical attention but information about the time of onset or duration of his disturbed nutritional condition were either unavailable or ambiguous, since the children returned to their homes following treatment, and were again exposed to malnutrition. Their poor intellectual functioning at any later point in time could hardly be interpreted as directly resulting only from early malnutrition.

The condition of Pyloric Stenosis (PS), which was the criterion of starvation in the present study overcomes the deficiencies of the above-mentioned studies. PS involves a defined period of starvation in early infancy not found to be associated with social deprivation or poverty. Upon surgical correction of this condition, the child resumes normal eating. This clear termination of starvation provides the researcher with definite boundaries of the starvation period.

A cause and effect relationship can best be established in an experimental study. The subject of starvation in infancy and its later effects can be experimentally studied only with animal subjects. To approximate a cause and effect relationship between starvation in infancy and subsequent learning difficulties in human subjects, the characteristics of starvation have to be studied in relation to the nature of subsequent learning abilities. In this process, other factors that could theoretically have an effect on learning abilities have to be carefully controlled.

Summary of the Study

Purpose

The aim of this study was to investigate the effects of defined brief periods of starvation in infancy on several subsequent learning abilities. The basic assumption was that starvation of varying degrees of severity, occurring at different times in infancy would have different effects on the various learning abilities assessed.

Subjects

A total of 144 white children from Monroe County participated in this study. The subjects were divided as follows:

1) Index cases. A group of 50 subjects, 44 boys and 6 girls, who had been treated for PS in infancy. The index cases were between 5 and 14 years old with a mean age of 9 years 2 months.
2) Sibling comparison group. A group of 44 subjects each of whom was a sibling of an index case. There were 44 children, 28 boys and 16 girls, in this group. Their ages ranged between 5 and 15 years with a mean age of 10 years and 1 month.
3) Matched comparison group. A group of 50 subjects, each of whom was matched by age, sex and father's level of education to the index cases.

Comparison between subject groups. Subjects for whom there was theoretical reasons to assume possible neurological damage due to conditions during pregnancy and birth or later injury, were excluded from all three groups. No significant differences (see Table 1) were found between the subject groups with regard to the following variables: duration of pregnancy, mother's age, birth weight, birth order, number of siblings and number of surgical operations in the child's history. The lack of such differences points to the conclusion that the variable of starvation, on which these groups did vary, led to differences in test scores across the different groups rather than any of the other factors.

Instruments

Rather than dealing with the global concept of intelligence, the present study focused on more functional concepts of learning abilities, especially those essential for "school learning". The following measures were included in the test battery: 1) Peabody Picture Vocabulary Test (PPVT); 2) Vocabulary; 3) Coding; 4) Digit Span (Auditory Memory), (tests 2, 3, and 4 were from the WISC); 5) Visual Memory (from the Hiskey-Nebraska Test of Learning Aptitude); 6) Raven Progressive Matrices; 7) Reading and 8) Arithmetic (tests 7 and 8 were from the Wide Range Achievement Test, WRAT).

In addition to testing the subjects, the parents were interviewed and asked to evaluate their children on the Parental Estimate of Development Scale (PEDS) and on the Vineland Social Maturity Scale (VSMS). The school teacher of each subject was asked to evaluate him on the Ottawa School Behavior Checklist (OSBCL).

Measurements of head circumference, height and weight were taken at the time of the testing as indicators of the subject's physical development.

General Research Design

The present study was designed to include the following intergroup and intragroup comparisons.

Intergroup comparisons. Comparisons were carried out between the index cases and the other two groups. This part of the study enabled the control of some genetic variables and home environment in the comparison between index cases and their siblings, and the control for sex and age in the comparison between the index cases and their matched controls.

It should be noted that of the 50 index cases only 6 were girls whereas of their 44 siblings 16 were girls. The differences between the index case group and the sibling group could be explained as stemming from sex differences between these groups. In order to test this assumption, comparisons were carried out between the 16 girl siblings and the 28 boy siblings. The values of *t* comparing all test scores of these two groups are presented in the Appendix (Table 66). None of the differences between the two groups of siblings was significant at the .05 level. Thus, it may be concluded that the differences between the index cases and their siblings were not caused by differences in sex.

Intragroup comparisons. Comparisons were carried out between subgroups of the index cases. This part of the study dealt with the relationship between the degree of severity and time of onset of starvation and their quantitative and qualitative effects on learning abilities. The intragroup comparisons controlled for the variable of the surgery for PS. The differences found among the index cases' subgroups could not be interpreted as resulting from surgery which they all had in common, but rather from the severity and time of starvation onset on which they varied.

Findings

Based on previous studies, there were not enough data to conclude that there are well-defined critical periods in brain development and even less data to determine the effect of starvation during these periods on _specific_ learning abilities. As a result, the central questions posed in this study were of an exploratory nature. These questions were: A. Does a brief period of starvation have a negative effect on the child's subsequent learning abilities? B. Does starvation affect general adjustment? C. If such effects are found, are there critical levels of starvation severity and are there critical times of starvation onset in relation to the different learning abilities studied? Answers to the above questions will be discussed in light of the Hypotheses tested.

A. _Does Starvation in Infancy Affect Learning Abilities?_

Intergroup comparisons. Hypothesis A which deals with the above question, states: The index cases have lower scores on all the tests of learning abilities than the groups of siblings and matched controls.

Based on the summary in Table 17, it may be concluded that the index cases differed significantly from the other two groups on the following tests: Peabody

Picture Vocabulary Test (PPVT), Vocabulary, Coding, Auditory Memory (Digit Span), Raven Progressive Matrices and Reading. In other words, verbal ability, speed and accuracy in visual motor coordination, immediate memory for digits perceived auditorily, nonverbal reasoning involving figural relations and reading abilities of the index cases were significantly affected by a period of starvation in infancy. Visual memory was not found to be significantly affected, but the statistical difference between the index cases and their matched controls was in the expected direction. For the Arithmetic Test, differences were found between the index cases and their siblings but not between the index cases and their matched controls.

Since all differences between the siblings and the matched controls were not significant ($p > .05$), the conclusion seems warranted that whatever differences were found between index cases and siblings, and index cases and matched controls, were not due to chance factors, and were actually related to the variable of starvation.

This strong effect of starvation on such a wide variety of learning abilities is in line with Dobbing's (1970) speculation that any restrictions of the brain growth during the "vulnerable period" seem to reset the entire growth program of the brain to a different and lower trajectory. This effect which may be irreversible, may result in a general rather than specific effect on mental functioning. The above findings also suggest that the time period between 3 and 60 days of age (which is the age range of P.S onset in this study) is within the boundaries of the "vulnerable period".

Correlations between test scores and severity of starvation. Hypothesis C predicts that the severity of starvation (weight deficit) experienced by the index cases will be negatively related to their scores on the learning ability tests. Hypothesis C was confirmed for all tests. Significant negative correlations were found between starvation severity and all test scores (see Table 27). The highest correlation found was between severity of starvation and scores on the Auditory Memory Test. The findings involved in testing Hypothesis C suggest that all the learning abilities measured were sensitive to variations in the degrees of starvation severity, higher levels of starvation having a more pronounced effect on learning abilities.

It should be noted here that the index of starvation severity ranged from a weight deficit of 41.9% to zero weight deficit. This wide range of starvation severity coupled with a wide range of test scores were favorable conditions for testing the correlations between the degree of starvation and the scores on the learning ability tests.

The strong generalized effect of starvation on learning abilities found under Hypothesis A should be examined in light of the significant negative relationship found under Hypothesis C, between the level of starvation and the test scores of the index cases. It was found that the more severe the starvation the lower the test scores. Since the group of index cases included subjects who had suffered from different degrees of starvation severity, it is possible that the scores of those who were severely starved were so low that even when combined with scores on other index cases, the group mean was still significantly lower than that of the other groups. Tables 3, 5, 7, 9, 11, 13, and 15 support the above explanation. The means of the high severity index cases, unlike those of the low severity group, were consistently lower than those of their siblings and matched controls, and lower than the mean scores of the moderate and low severity index cases.

Intergroup comparisons within each level of starvation severity. The findings suggested that since severity of starvation is such a central factor affecting learning abilities, comparisons between the index cases, siblings and matched controls, should be carried out across each level of starvation severity.

Table 18 presents the values of *t* for the comparisons between the index cases in each level of starvation severity, their siblings and matched controls.

Findings presented in Table 18 for the Coding and

Auditory Memory Tests show that the high severity index cases had significantly lower coding and auditory memory abilities as compared to both their siblings and their matched controls. No difference was found between the siblings and the matched controls on these two tests. Differences between index and comparison groups on the Coding Test were not significant for the moderate and low severity groups. It may thus be concluded that visual motor (eye-hand) coordination, speed and accuracy of learning a new code, as measured by the Coding Test, were significantly affected by the condition of starvation in infancy. This condition was isolated as the main variable on which the index cases differed from the two other groups and on which the high severity index cases differed from the moderate and low severity index cases. On the Auditory Memory Test the differences between the index cases, their siblings and matched controls, were consistently present in all groups of starvation severity. This effect was so marked that even the low severity index cases had significantly lower scores on the Auditory Memory Test as compared to the other two groups. This difference between the index cases and the other two groups, regardless of the levels of starvation severity, raises questions about other conditions aside from starvation in infancy that the index cases had in common which could also have hindered their auditory memory independent of starvation. This possibility does exist and it would be important to look into this question in future research. However, it has to be noted that the above findings for the Auditory Memory scores may also reflect the sensitivity or vulnerability of this test to the lowest levels of starvation severity. A significant correlation between Auditory Memory and severity of starvation was found ($r=.431$, $df=49$, $p <.01$). This correlation coefficient was the highest of all correlation coefficients involving starvation severity and scores on tests of learning abilities. Another finding which supports the assumption that the differences between the index cases and the other groups was due to starvation in infancy, involves the two-way analysis of variance presented in Table 35. In this analysis it was found that significant differences on the Auditory Memory Test scores ($p < .05$) exist between the high, moderate and low severity of starvation index cases. In other words, if variations in severity of starvation significantly affect the Auditory Memory Test scores, it may be concluded that starvation in infancy affects subsequent auditory memory.

The analysis of the Visual Memory Test scores did not include paired comparisons between index cases and their siblings or between siblings and matched controls. These comparisons would involve pairing children of different ages for whom the test of visual memory included two separate tasks. For children up to 10 years of age, the visual memory task was for color while for the older children it was for digits. The only analysis of the Visual Memory Test scores carried out under Hypothesis A were the comparisons between the index cases and their matched controls across all levels of starvation severity. The index cases in both the high and moderate severity of starvation groups were found to have poorer visual memory ($p < .05$) as compared to their matched control subjects. Although the validity of the findings for the Visual Memory Test could not be tested by examining the consistency of findings for the comparisons between the index cases, their siblings and matched controls, the findings for the Visual Memory Test strongly suggest that the index cases' visual memory was affected by starvation in infancy. These results are in line with the previously discussed findings for Coding and Auditory Memory. Since Coding, Auditory Memory and Visual Memory involve short-term memory and attention, it can be concluded that these abilities are significantly affected by starvation in infancy.

The findings involving the scores on the Peabody Picture Vocabulary Test (PPVT), Raven Progressive Matrices, Vocabulary, Reading and Arithmetic, present several interpretation problems. For the scores on the PPVT, differences were found only between the moderate severity index cases and their matched controls ($p < .05$). It cannot be concluded on the basis of the findings for this test that a child's verbal ability as measured by the PPVT was affected by starvation in infancy. The significant difference between the index cases and the matched controls in the moderate severity group could be explained by the fact that the matched controls in this group had higher PPVT scores as compared to the siblings. Although this difference was not significant ($p > .05$), it was large enough to yield a significant difference between the index cases and the matched controls and no difference between the index cases and their siblings.

For the scores on the Raven Progressive Matrices, significant differences were found between the index cases and siblings ($p < .01$) as well as between the index cases and their matched controls ($p < .05$) in the moderate severity group but not in the high severity group. Differences between the index cases, the siblings and matched controls in the high severity group were in the expected direction, i.e. the index cases having lower scores than the other groups, but these differences did not reach the .05 level of significance.

The standard deviation of the differences in scores between the high severity index cases and their siblings was 6.33 and between the high severity index cases and their matched controls 6.71. The standard deviations of the differences in scores between the moderate severity index cases and their siblings was 4.79 and between the moderate severity index cases and their matched controls

5.77. These differences in standard deviations could at least partially account for the fact that significant differences were found between the moderate severity index cases and their comparison groups, but not between the high severity index cases and their comparison groups.

For the subjects' achievement in reading and arithmetic, it may be concluded that there were several significant differences between index cases and one of the comparison groups, as presented in Table 18. These differences were inconsistent, i.e. did not appear in the comparisons of index cases to the two comparison groups and were also coupled in some cases with significant differences between the group of matched controls and that of the siblings. It should be noted that although no significant differences were found between the mean test scores of all siblings as compared to all matched controls, such differences were found (see Table 18) in a few comparisons between the siblings and matched controls for index cases of a certain level of starvation severity. These differences should be viewed in light of the following facts: Of all the families of index cases contacted, 57.3% volunteered to participate in the study and only 29% of the contacted parents of matched control children agreed to participate. The parents of the index cases were more genuinely interested in the study as a follow-up of their child's medical condition of PS in infancy. The parents of the control children probably volunteered because they were interested in obtaining an evaluation of their child's learning abilities, especially when their children had learning problems.

Summary

In summary, it may be concluded that the coding ability and the auditory memory ability are most sensitive to starvation in infancy and to variations in the degree of severity of this starvation. While the coding ability is affected only by the high severity of starvation (weight deficit of 21% and over), the auditory memory is the only ability affected even by low severity of starvation (from zero to 10% weight deficit). An effect of starvation in infancy on subsequent achievement in reading and arithmetic was suggested by the findings, but this effect was less consistent than the effect of starvation on the child's visual-motor coordination, speed and accuracy in learning a new code, and auditory and visual short-term memory and attention. Theoretically, the siblings and the matched control subjects were not expected to differ significantly on any of the tests. The differences found between these two groups suggest that some of the subjects within these groups had some learning disorders. Despite this fact, the index cases were consistently found to have lower test scores than both their siblings and their matched controls. The finding that the index cases had lower test scores than the comparison subjects despite learning problems of the comparison subjects, strengthens the conclusion that the starvation period experienced by the index cases had a long-lasting effect on their learning abilities.

Findings in light of research data from other studies. The Coding Test or, as Wechsler (1958) calls it, "The Digit Symbol or Substitution Test is one of the oldest and best established of all psychological tests". The subject is required on this test to associate certain symbols with certain other symbols, the speed and accuracy with which he does it serve as a measure of his intellectual ability. Based on extensive studies of initial and later effects of diversive forms of brain insult, Smith (1968) points out that the substitution test was consistently the most sensitive and reliable single indicator of cerebral dysfunction. The amount of functional impairment manifested on the substitution test depends on various characteristics such as size, location and nature of the cerebral dysfunction as well as other characteristics such as age and sex of the subject. Wechsler (1958) concludes that with few exceptions patients with either overt or covert "brain damage" show the most frequent and/or greatest impairment in substitution tests. The validity of this test was demonstrated in studies of children with minimal brain dysfunction (Stevens et al., 1967), cerebral palsy (Klapper and Birch, 1967), and diverse neurologic disorders (Reed, Reitan and Klove, 1965). All of these studies revealed that the most consistent and greatest impairment was manifested in the substitution test. For example, Reed, Reitan, and Klove (1965), had found that of 27 different measures yielded by Wechsler and Halstead-Reitan tests, Digit Symbol showed the lowest number of brain-damaged children with higher scores than those of equated controls (only 2 of 50).

WISC scores are usually analyzed in terms of verbal scale-performance scale differences. Bannatyne (1968) suggested that the WISC subtest scores of genetic dyslexic readers are best analyzed in terms of categories he calls spatial, conceptual, and sequential. The sequential category includes the Digit Span, Coding and Picture Arrangement Tests. These tests require the ability to retain sequences of auditory and visual stimuli in short-term memory storage. Bannatyne (1971) reports that genetic dyslexic readers receive their lowest scores in the sequential category. Rugel (1974) recently reviewed 25 studies which reported WISC subtest scores of disabled readers. He also found that disabled readers have deficits in short-term memory and attentional processes.

In summary, the Coding Test and the Auditory Memory Test which were found to be most significantly affected by starvation in infancy, were also found in numerous studies to be significantly related to brain damage or learning dysfunctions. In other words, those abilities affected by starvation in infancy are also associated with brain dysfunctions and learning disorders. This finding strengthens the causality chain of starvation in infancy affecting normal brain development which in turn affects the abilities involved in coding and in auditory memory.

Bannatyne (1968) indicates that the Auditory Memory and Coding Tests require the ability to attend to, and retain sequences of, auditory and visual stimuli in short-term memory storage. The fact that short-term memory and attention were significantly affected by starvation in infancy was also supported by the findings for the Visual Memory Test which heavily involves both short-term memory and attention.

B. Does Starvation in Infancy Affect General Adjustment?

The basic question about the effects of starvation in infancy on subsequent learning abilities has been discussed so far with respect to the cognitive abilities measured by the psychometric tests. This same question will now be dealt with in relation to behavioral aspects of adjustments to every day life, as measured by the Parental Estimate of Development Scale (PEDS), Vineland Social Maturity Scale (VSMS), and the Ottawa School Behavior Checklist (OSBCL).

Intergroup comparisons. Hypothesis B predicted that the index cases would have lower PEDS, VSMS, and higher OSBCL scores than their siblings and matched controls. None of the differences between these groups met the critical values for the .05 point of significance. The insignificant differences found between the index cases, siblings and matched controls on the behavioral measures may be partially explained by the fact that the total score for the group of index cases included scores of subjects in all three levels of starvation severity, the scores of the moderate and low severity subjects both of which were closer to the means of the other groups than to those of the high severity subjects pulled the mean of all the index cases closer to the mean of their siblings, thus eliminating the differences between these groups. It is interesting to note that, with the exception of the scores on Immaturity and Overactivity, the high severity index cases had more conduct and personality difficulties as well as other behavioral problems in school, as indicated by their higher factor scores and total scores on the OSBCL. Similar results were found in the analysis of the VSMS scores. The high severity index cases had the lowest mean score on the VSMS, suggesting that these subjects were evaluated by their parents as less mature compared to their siblings and matched controls.

Correlation between measures of adjustment and severity of starvation. The strong negative relationship between the index of starvation severity and the subjects' test scores was also found for the PEDS (Parental Estimate of

Development Scale). A significant correlation between starvation severity and scores on the PEDS was found, ($r=0.367$, $df=49$, $p < .01$) In other words, the parental evaluation of their child's overall development based on the child's behavior, indicates clearly that the higher the degree of starvation severity the lower the parental estimation of their child's development and predicted potential. Other studies on the PEDS (Heriot, 1972) show that parents are very accurate in their estimation of their child's intellectual abilities. The mean estimation of IQ based on the PEDS was found to be only 3.5 points above the subjects' measured IQ. Rosental and Jacobson (1968) highlight the utility of using parental scales in the diagnosis of academic underachievement.

The factors of Immaturity, Overactivity, Conduct, Personality and the total Ottawa School Behavior Checklist, were not significantly correlated with starvation severity. The same was true for the Vineland Social Maturity Scale. In summary, the only behavioral measure found to be negatively affected by the degree of starvation was the PEDS. Neither teacher's evaluation of subjects' behavior nor parental evaluation of their children's social development on the VSMS, were found to be related to starvation severity. The difference in the results of the above correlations could have been caused by the fact that the PEDS is more heavily loaded with the intellectual and academic factor which was found to be strongly related to starvation severity, while the other measures were higher on the social and general adjustment factors.

Intergroup comparisons within each level of starvation severity. The values of *t* for the separate comparisons between the subject groups within each severity level show that the high severity index cases had higher VSMS scores than their siblings and matched controls ($p < .05$). For the PEDS scores, significant differences were found in the moderate severity group between the index cases and their siblings ($p < .05$) and between the index cases and their matched controls ($p < .01$). Since these differences were found only for the moderate severity group and not for the high severity group, it cannot be concluded that starvation in infancy affected the subjects' scores on the PEDS. The low severity index cases were found to have significantly higher scores than their siblings. The groups of siblings and the groups of matched controls in all three levels of severity did not differ on the behavioral measures with one exception. The siblings in the moderate severity group were found to have significantly higher scores on the VSMS as compared to the matched controls. This finding adds to the previously discussed assumption that the matched control subjects had learning difficulties.

Summary. An interesting consistency exixts between the findings for the cognitive tests and the findings for the behavioral measures. Low severity of starvation was not found to affect any of the measured aspects of behavior, as was the case for most of the learning abilities tested. High severity of starvation was associated with lower social maturity scores on the VSMS as compared to the siblings and matched controls. In other words, high levels of starvation were associated with deficits in social maturity as evaluated by the parents.

Cognitive tests and behavioral evaluations strongly confirm the assumption that a period of severe starvation in infancy hinders the child's normal development resulting in irreversible deficits in learning abilities and general adjustments to everyday situations.

The fact that a period of starvation occurring during the first months of life was found to have a significant effect on subsequent learning abilities, suggests that this period is a critical period in the development of the affected abilities.

C. Are There Critical Periods in the Development of Learning Abilities?

The following pages deal with the question of critical periods during which the occurrence of starvation may result in permanent damage to specific subsequent learning abilities. In attempt to answer the above question, the predictions in Hypotheses D and E were tested. Hypothesis

D predicted differences between test scores of subjects who had suffered from starvation at different periods of time in infancy. Hypothesis E predicted an interaction effect between starvation severity and its time of onset. For the purpose of testing the above Hypotheses, the index cases were divided into three groups based on their age (in days) at the time of starvation onset, i.e. the day on which the symptoms of PS were discovered by the parents. The level of starvation severity which was found to be significantly correlated with all learning abilities measured, had to be considered in answering the question of critical periods. The subjects in each group of starvation onset (1-20, 21-30, or 31-60 days of age) were divided into three subgroups based on the degree of starvation severity. This subdivision formed 9 cells of subjects. In order to eliminate cells with only one or two subjects, subjects were grouped into the above three groups of starvation onset and there was no finer breakdown of starvation onset.

Tables 28-33 show no statistically significant difference between the test scores of the subjects on the three groups of starvation onset. In other words, test scores of subjects for whom starvation onset was between 1 to 20 days of age did not differ from the scores of subjects for whom starvation started between 21 and 30 days or between 31 to 60 days of age.

These findings suggest that the above three periods of starvation onset did not differ with regard to their effects on the development of learning abilities. This conclusion should be considered in light of the fact that the whole period of starvation, including all of the above three groups of starvation onset, was found to be strongly associated with deficits in learning abilities and thus can be considered as a critical period in their development. The upper boundaries of this larger critical period cannot be clearly determined in the present study since there was only one subject for whom starvation onset occurred after 60 days of age. For this subject starvation started at the age of 102 days. Although no conclusions can be reached on the basis of only one subject, it is interesting to note that this subject scored above average on all tests with the exception of the PPVT and the Vocabulary Test on which he was average. As for the lower limit of the critical period, it must be concluded that starvation onset between 1 and 20 days of age does not have a different effect on learning abilities than a later period of starvation onset up to 60 days. In addition to an insignificant difference between the three groups of starvation onset, no significant difference was found between the subgroups of starvation onset divided by starvation severity. It may be concluded that no interaction effect exists between starvation onset and its degree of severity. However, there are several findings that suggest an interesting trend in the results.

The highest value of F for the comparison between the three groups of starvation onset (F=2.049, df=2,40) was found in the analysis on the PPVT scores. Looking at Table 28, it becomes apparent that the subjects for whom starvation started at the age of 31 to 60 days, had the lowest mean score on the PPVT as compared to the scores of the other two groups. The highest value of F (F=2.178, df=4,40) for the comparisons between the subgroups was found for the scores on the Visual Memory Test (Between Cells, Table 37). The highest mean score (Table 36) was the mean score of the high severity index cases whose onset of starvation was between 1 and 20 days of age. The lowest score on this test was the score of the high severity index cases whose onset of starvation was between 31 and 60 days of age. In other words for the 1-20 days starvation onset group, starvation, regardless of its severity, had no effect on visual memory. Only for subjects with starvation onset between 31 and 60 days was such an effect found.

The Visual Memory Test involves attention and short-term memory for visually presented stimuli. The PPVT calls for recognition of the right answer among four picture choices. When the child examines the pictures he has to remember the meaning of the stimulus word and match it with each one of the possible answers or remember all four answers and make a choice among them, i.e., the Visual Memory Test and the PPVT involve short-term memory and attention to visually presented stimuli. The selective effect of starvation onset between 31 and 60 days, especially on the Visual Memory and PPVT Test, suggests a selective effect on the above period on the learning abilities involved in these two tests. The lowest score on all tests (with the exception of the Vocabulary Test) was the score of the index cases whose onset of starvation was between 31 and 60 days of age. It must be stressed again that these findings were not statistically significant and that no conclusions can be reached about starvation onset after 60 days of age. However, the high consistency of these findings across all tests of learning abilities suggests the speculation that starvation between 31 and 60 days of age has the most severe effect on subsequent learning abilities, especially on short-term memory and attention to visually presented stimuli.

D. Are There Critical Periods in the Development of General Adjustment Abilities?

The question of critical periods in infancy was studied with regard to the parents' and teachers' evaluation of the subjects' development and behavior. As predicted by Hypothesis F, subjects for whom starvation started at different periods in infancy differ in their behavior at home and in school as evaluated by the Ottawa School Behavior Checklist (OSBCL), Vineland Social Maturity Scale (VSMS), and the Parental Estimate of Development Scale (PEDS). An interaction effect between the degree of starvation severity and the time of starvation onset was predicted by Hypothesis E.

The time of starvation onset was found to affect the scores on the OSBCL. Data presented in Table 58 shows that those index cases for whom starvation onset was between 21 and 30 days of age, had significantly more problems related to immaturity, overactivity and conduct as compared to the two other groups of starvation onset. In other words, parental evaluation of the subjects did not show significant differences between the groups of starvation onset, while teachers' evaluations did show such differences on the Immaturity, Overactivity, and Conduct Factors of the OSBCL. Onset of starvation during the period between 21 and 30 days of age was found to affect the scores on the factors of Immaturity, Overactivity and Conduct, suggesting that this period is critical in the development of these factors. It seems essential at this point in the discussion to look into some of the items included in these three factors.

The Immaturity Factor includes the following items: gets out of seat, destroys work, hits children, plays with toys in class, plays with school equipment in class (erasers, books, etc.), defaces work, draws on workbooks, makes noises with objects (ruler, deskcover, etc.), mutters and grimaces. Some of the items on the Overactivity Factors are: hits children, pushes children, comments aloud, buts in with answers, and interrupts teacher. Some of the items on the Conduct Factor are: hits children, pushes children, cheats on tests, and wanders around classroom. The items in the Immaturity, Overactivity and Conduct Factors seem to be related to the child's inability to control his behavior in the classroom and to attend to one task for a prolonged period of time. The findings in this study suggest that some basic mechanisms necessary for such a control are developed early in infancy around the third and fourth week after birth.

A defined relatively brief critical period was isolated in the present study. Other studies (Cravioto and Robles, 1965 ; Birch, 1971) suggest that longer periods of malnutrition in infancy are critical to the normal development of cognitive functioning and general adjustment. Cravioto and Robles (1965) suggested that malnutrition occurring up to 6 months of age is critical to the development of mental abilities. Birch (1971) reported that malnutrition lasting for a period longer than the first four months of life has an irreversible effect on intelligence. In the present study a brief period of starvation occurring earlier than Birch's suggested critical period of four months, was examined in relation to learning abilities. It should be stressed that starvation as defined in the present study involved severe limitations on all food and water reaching the body cells, whereas most other reported studies dealt mainly with protein deficiency. In most other studies malnutrition started after some period of nursing during which the child was well nourished. In the present study, starvation onset could have occurred immediately after birth. In summary, severe starvation does not have to last four or six months before it leaves its permanent effects. Brief periods of starvation occurring during the first two to three months of age affect the child's learning abilities and general adjustment.

Effects of Starvation in Infancy on Physical Development

The distribution of height, weight and head circumference of the index cases was not found to be significantly different from that of their parents, siblings or matched controls. No differences were found between the groups of index cases who suffered from high, moderate and low severity of starvation. Since these measures represented the physical development of the subjects, it can be concluded that a brief period of starvation in early infancy does not have an irreversible effect on body growth. Early motor development of the index cases based on the date they started to walk, was found to be significantly correlated with the severity of starvation experienced by the subjects ($r=.400$, $df=49$, $p < .01$). In other words, a higher degree of starvation was associated with slower motor development. Seven of the index cases had phonetic speech problems in their developmental history.

None of the siblings and four of the matched control subjects had similar problems. These findings suggest that a brief period of starvation may lead to difficulties in the development of speech. In summary, while starvation in infancy was not found to affect gross physical development of the body, it was found to delay the motor development of walking. The findings also suggest that speech problems may be related to starvation in early infancy.

Summary

This study was designed to test the effects of a brief period of starvation, not related to socioeconomic factors, on subsequent learning abilities and general adjustment.

The major questions posed by this study were: 1) Does a defined period of starvation occurring within the first three months after birth, have an effect on subsequent learning abilities and general adjustment? 2) Are there critical periods within the first three months of age during which starvation may cause irreversible damage to the development of specific learning abilities? Any answer to these questions would imply a cause and effect relationship between starvation and deficits in learning abilities. The latter can be demonstrated in an experimental study and can only be approximated in a field study. In order to isolate starvation as the cause of differences among the subjects' test scores, two different methods were used. 1) Control of variables theoretically known to affect intellectual development, specifically age, sex, socioeconomic status, parental education, complications during pregnancy, delivery, birth weight, birth order, number of siblings, medical problems and surgical operations in the child's life history. Since the number of subjects in the study was relatively high, it could be assumed that chance factors would randomize the distribution of any other unconsidered variables among the different subject groups. 2) Conclusions were based on consistent findings of the comparisons between the index cases, their siblings and matched controls, and across different levels of starvation severity.

With these considerations in mind, the following statements about the findings can be made: eye-hand coordination, attention and short-term memory as measured by the Coding, and Auditory Memory tests respectively were most significantly affected by starvation in infancy. Only the high level of starvation severity involving 21.0% to 41.9% weight deficit affected the abilities measured by the Coding Test, i.e. speed and accuracy in learning a new code requiring eye-hand coordination, short-term memory and attention. All levels of starvation severity, especially the high levels, were found to affect the Auditory Memory Test scores measuring short-term memory and attention to auditorily perceived digits.

Since the Coding Test and the Auditory Memory Test both involve short-term memory and were both found to be affected by starvation, it may be concluded that starvation in early infancy can cause long lasting damage to cognitive processes involving short-term memory and attention. This conclusion was confirmed by the findings for the Visual Memory Test which also involved the abilities of short-term memory and attention.

The Coding and Auditory Memory Tests have been found by others to yield significantly lower scores for subjects identified as having brain dysfunctions or learning disorders (Bannaytne, 1971, Rugel, 1974, Wechsler, 1958). In other words, the same abilities that were most significantly affected by starvation were also found to be associated with brain dysfunctions and learning disorders. This relationship strengthens the causal chain between starvation and learning disorders.

An effect of starvation on achievement in reading and arithmetic was suggested by the findings. Since this effect was not consistent throughout all comparisons of the index cases with the other groups, no definite conclusions could be reached.

Of all the behavioral measures testing general adjustment in this study, only the Parental Estimate of Development (PEDS) was significantly correlated with starvation severity. Higher levels of starvation were associated with lower parental estimates of the children's development. High severity of starvation was found to hinder subsequent social maturity as evaluated by the parents on the Vineland Social Maturity Scale.

Starvation onset between the ages of 1 and 20 days, 21 and 30 days, and 31 and 60 days were not found to have a significantly different effect on any of the learning abilities measured. Though not statistically significant, there was a consistent trend on all tests (with the exception of Vocabulary) indicating that the period between 31 and 60 days of age is most critical in the development of the measured learning abilities.

In the analysis of the behavioral measures, starvation onset between the ages of 21 and 30 days was found to affect the subject's scores on the Immaturity, Overactivity, and Conduct Factors on the OSBCL.

The Immaturity, Overactivity and Conduct Factors involve items reflecting the child's inability to control his behavior in class and to attend to one task for a prolonged period of time. Since starvation onset between 21 and 30 days of age selectively affected these abilities, it can be concluded that starvation onset between 21 and 30 days after birth, is critical in the development of mechanisms involved in self control of behavior and attention span.

The physical growth of the body evaluated by the measures of head circumference, height and weight, were not found to be significantly affected by starvation. Gross motor coordination reflected by the early development of walking skills was found to be significantly affected by starvation.

Implications

The findings in the present study have several theoretical and practical implications. The fact that a defined period of starvation occurring within the first three months of life has irreversible effects on learning abilities, suggests that this period is a critical period in the development of the abilities studied. The abilities found to be most sensitive to starvation were eye-hand coordination, short-term memory and attention, as well as abilities to control behavior indicative of overactivity and immaturity. Numerous earlier investigators have concluded that "attentional" abilities are a necessary prerequisite for other kinds of learning (Hallahan and Cruickshank, 1973). A child who cannot attend to his environment will have difficulties in developing concepts that will help him understand his environment and adjust to it intelligently.

It is obvious that this study strengthens the position of the environmentalists in the nature-nurture controversy on intelligence. If a brief period of starvation occurring in early infancy has such a significant effect on the child's learning abilities, it must be concluded that manipulations of environmental variables such as early nutrition can lead to differences in abilities that are basic for intellectual development and behavior. Any attempt to erase or decrease differences in intelligence between social or racial segments of the population must begin with adequate nutrition of the mothers and infants. Overlooking this early critical period in the development of learning abilities may hinder latter attempts to close the intellectual gap between these groups.

The affluent middle class of the Western world takes it for granted that modern technology has contributed to the quality of life. In fact, technology has worsened life for poor populations (Shneour, 1974). As more countries enter the technological race and more women go out to work, breast feeding has decreased and infants face malnutrition in the early months of life with increasing frequency. The vast majority of these malnourished infants survive with all the potential mental and physical consequences of malnutrition.

Shneour (1974) concludes his recent book, *The Malnourished Mind*, by the following statement which summarizes the practical scope of the problem:

> "Early-life malnutrition is a probable cause of brain deficiencies. The problem is now a social one for which a scientific solution exists. Implementation of that solution lies where social priorities are established--in the political sphere. Scientific knowledge is not of itself good or evil. It is in the wisdom of its application that the fate of mankind will continue to be determined" (p. 186).

In addition to the necessary steps needed for prevention of future learning problems, action must be taken to engender attentional skills in children exposed to starvation in infancy. Although direct damage to the brain is irreversible, there are psychoeducational procedures such as described by Strauss and Lehtinen (1947), Luria (1961), Cratty and Martin (1969), and Bandura (1962), for helping the child cope with his problems. Early treatment of the problem can avoid long periods of suffering and a greater waste of human potential.

FOOTNOTES

[1] The selection of matched control subjects was done with the help of Dr. Klaus J. Roghmann, Associate Professor of Sociology and Pediatrics, University of Rochester, Rochester, New York.

[2] Dr. James Heriot is Assistant Professor of Pediatrics, Psychiatry and Psychology, University of Rochester, Rochester, New York

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APPENDIX 1

THE UNIVERSITY OF ROCHESTER
SCHOOL OF MEDICINE AND DENTISTRY

SCHOOL HEALTH PROGRAMS
1545 MT. HOPE AVENUE
ROCHESTER, N. Y. 14620

(716) 275-277

, 1973

Dear Mr. & Mrs.

We are conducting a follow-up study of individuals who had an operation for pyloric stenosis in early infancy, and we will appreciate your cooperation in allowing your children to participate in this study. We are interested in seeing the child who had pyloric stenosis and a sibling who is closest in age and of the same sex.

The purpose of the study is to find out whether the condition of pyloric stenosis is associated with the way children learn and their physical development. There are very few studies in the medical literature on this particular topic, and we feel that our proposed study will add a great deal to medical knowledge. We have discussed the matter with the surgeons who operated on your child and they are willing for us to proceed.

All that would be required is for you to bring your children to see us so that we can talk to you, measure height and weight, and do some standard estimates of children's learning abilities.

The entire procedure will take about 2 hours, and there will be no charge. The results of the tests can be made available to you, if you so wish, but will otherwise be held in confidence.

If you are willing to participate, please complete the bottom part of this page and mail it to us. We can then call you to set up a convenient appointment time. If you have any questions you may cal me any weekday afternoon after 3 p.m. at 473-6810.

Sincerely yours,

Mrs. P. Klein, M.A.
Philip R. Nader, M.D.
Gilbert A. Forbes, M.D.

- -

Pyloric Stenosis Study (Confidential & Voluntary)

I give permission for my children to participate in the pyloric stenos study which will include a learning evaluation; height, weight; and co lection of pertinent school information.

Child's Name: ______________________ Birthdate: ________ Sex: _
School: ____________________ Teacher's Name: ______________
Brother's (sister's) name: ______________ Birthdate: ________ Sex: _
School: ____________________ Teacher's Name: ______________
My Signature: ______________________________________
Address: ____________________________________ Phone: ________

APPENDIX 2

THE UNIVERSITY OF ROCHESTER
SCHOOL OF MEDICINE AND DENTISTRY

SCHOOL HEALTH PROGRAMS
1545 MT. HOPE AVENUE
ROCHESTER, N. Y. 14620

(716) 275-2772

, 1973

Dear

The College of Education and the School Health Program, Department of Pediatrics of the University of Rochester, are studying children's learning abilities. We will be able to evaluate a limited number of children with regard to their overall learning ability, strengths and weaknesses in their cognitive profile, or the way they learn best; as well as their achievement level in reading and math. We will also counsel their parents as to meaning of the results of the evaluation.

Because you have previously cooperated with the Rochester Child Health Study, we are contacting you to see if you would like to have your child ____________ participate in this study.

We would need you to bring your child to our office. We will measure the child's height and weight and do the evaluations of children's learning abilities. The entire time will take less than 1 1/2 hours. The tests will yield a profile of the child's learning abilities that may help you in understanding your child's learning potential.

If you wish to have your child participate, please complete the bottom part of this page and mail it to us. Mrs. Klein will then call you to set up a convenient appointment time. If you have any questions you may call Mrs. Klein Monday through Thursday after 3 p.m. at 473-6810.

Pnina Klein, M.A.
Philip R. Nader, M.D.
Gilbert Forbes, M.D.

Study of learning abilities (confidential & voluntary)
I would like my child to participate in the evaluation study of learning abilities.

Child's name: ______________________
School: ______________________ Grade: ____________
My signature: ______________________
Address: ______________________ Phone: ____________
____

APPENDIX 3

CHILD'S NAME: ____________, ________ Case No. ________

Date: __________

PARENTAL INTERVIEW

1. PREGNANCY

Duration __________, Edema __________, Toxemia __________

Blood pressure __________, Proteinemia __________,

Seizures __________, Bleeding __________ Other __________

Drugs taken by mother ____________________

Mother's age __________

2. DELIVERY ____

____

____

3. NEONATAL

Color ________, Jaundice ________, Cry ________, Feeding ________

4. GROWTH AND DEVELOPMENT

Physical growth of the body ____________________

Motor development ____________________

Development of speech ____________________

5. ILLNESSES AND HOSPITALIZATIONS

Problem ____________________ Age ________

Infection __________ High Fever __________

Hospitalization ____________________ Age ________

Psychological trauma ____________________

6. DISORDERS IN FAMILY

Type of disorder ____________________

Relation to child ____________________

7. SIBLINGS

No. __________ Sex __________ Age __________

8. PARENTAL EDUCATION

Father ______________________ Mother ______________________

Occupation ______________________ ______________________

9. PARENTS' HEIGHT

Father ______________________ Mother ______________________

10. CHILD'S GENERAL ADJUSTMENT TO:

Home (siblings, parents) ______________________

____

School ______________________

____

Friends ______________________

____

APPENDIX 5

Selected Items from the
Ottawa School Behavior Checklist (OSBCL)
(Pimm and McClure, 1969)

4. Gets out of seat
7. Destroys school equipment
9. Hits staff
10. Hits children
11. Distracts other children by clowning
15. Pushes children
16. Plays with toys in class
18. Defaces work
20. Kicks children
39. Doesn't complete work
44. Throws objects
47. Wanders around classroom
54. Talks to imaginary persons
55. Cries
62. Looks at the floor when talking
64. Speaks in a whisper
70. Makes strange noises
78. Bites nails
83. Falls asleep
95. Plays alone

APPENDIX 6

Tables 62-66

TABLE 62

Mean Scores and Standard Deviations of Index Cases on the Auditory Memory Forward Subtest

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\overline{X}$	9.00	6.56	10.60	8.18
	SD	1.00	3.81	4.16	3.89
	N	3	9	5	
21-30	$\overline{X}$	8.83	9.17	11.50	9.63
	SD	1.94	2.79	2.65	2.55
	N	6	6	4	
31-60	$\overline{X}$	5.50	11.75	9.63	9.13
	SD	5.45	2.36	2.20	3.85
	N	4	4	8	
Column means & SD	$\overline{X}$	7.85	8.47	10.35	
	SD	3.44	3.73	2.89	

TABLE 63

Summary of Two-Way Analysis of Variance for the Auditory Memory Forward Subtest Scores

Source	SS	DF	MS	F
Between Rows	10.04	2	5.02	0.495
Between Columns	57.01	2	28.51	2.811
Between Cells	101.91	4	25.48	2.512
Within Cells	405.71	40	10.14	

Note. - All values of F were not significant at the .05 level.

TABLE 64

Mean Scores and Standard Deviations of Index Cases on the Auditory Memory Backward Subtest

Age at starvation onset		Level of Starvation Severity			
		High	Moderate	Low	Row means & SD
1-20	$\overline{X}$	7.00	6.56	7.40	6.88
	SD	2.65	3.17	0.89	2.50
21-30	$\overline{X}$	7.00	5.33	8.75	6.81
	SD	3.52	1.21	1.26	2.61
31-60	$\overline{X}$	5.25	6.75	9.63	7.81
	SD	4.57	2.99	2.67	3.62
Column means & SD	$\overline{X}$	6.46	6.21	8.77	
	SD	3.50	2.59	2.14	

TABLE 65

Summary of Two-Way Analysis of Variance for the
Auditory Memory Backward Subtest Scores

Source	SS	DF	MS	F
Between Rows	0.41	2	0.204	0.026
Between Columns	50.67	2	25.33	3.260*
Between Cells	27.44	4	6.86	0.883
Within Cells	310.88	40	7.77	

$p < .05$

TABLE 66

Mean Scores and Standard Deviations on Learning Ability Tests for the Boy and Girl Siblings and Values of t for the Comparison Between Them

Group of subjects		PPVT	Vocabulary	Coding	Auditory Memory	Visual Memory	Raven	Reading	Arithmeti
girls (N=16)	$\bar{X}$	110.63	11.38	12.69	10.50	121.19	60.18	105.31	107.00
	SD	11.37	2.15	1.86	1.46	29.48	6.31	9.39	11.69
boys (N=28)	$\bar{X}$	114.25	11.68	12.43	10.75	113.79	60.30	111.82	104.18
	SD	16.04	2.79	2.62	2.03	21.47	4.81	17.68	10.39
value of t (df=42)		0.779	0.367	0.340	0.423	0.935	0.068	1.335	0.808

Note. - For all values of t, $p > .05$.